Open Access Multidisciplinary Online Magazine

Agri-India TODAY

Monthly Magazine-cum-eNewsletter

ISSN : 2583-0910

Volume 05 | Issue 08 | August 2025

www.agriindiatoday.in

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ISSN : 2583-0910
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Article ID : 05/VIII/01/0825

VALUE ADDED PRODUCTS OF NEEM: A POLYHEDRAL ELIXIR FOR EFFECTIVE HEALTH MANAGEMENT

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Abstract

Health diseases prevalence is escalating globally, with India experiencing a significant rise in cases. Conventional treatments often come with side effects and high costs, underscoring the need for natural, affordable alternatives. These are the natural remedies to mitigate diabetes using combination of herbal ingredients. The products are mixture of natural ingredients including neem, aloe vera, cinnamon, fenugreek, amla and bael is known for potential anti-diabetic, anti-pyretic and anti-inflammatory properties. This study proposes a herbal formulation of soaps, shampoos, juices and healthcare powder effectively recommended for reducing diabetes. It focusses on providing a holistic approach for the control of various health ailments spreading rapidly over a global scale. While the products are natural and cost-effective, it requires consistent utilization over an extended period to achieve noticeable effects. The proposed solution aims to provide a sustainable approach to disease management, particularly beneficial for populations with limited access to conventional medical treatments. It emphasizes that while the product may take longer to show effects compared to conventional medicines, it could be safer, more natural approach to managing diabetes when combined with a healthy lifestyle.

Introduction

Neem has several curative properties and it is used in curing the following ailments which includes various skin disorders, hair fall issues, dental problems, gastrointestinal diseases and dandruff. The neem tree is a tropical evergreen tree originated from India and is also found in South-East countries. All the plant parts contain compounds with evident antiseptic, antiviral, antipyretic, anti inflammatory, anti ulcer and antifungal characteristics. Neem is effectively used all over the world due to these miraculous properties. Neem can be effectively used for curing diabetes, hypertension and several other health problems. It is good to consume neem leaves in an empty stomach to prevent the alimentary canal from pathogens. It is also recommended that the use of neem leaves which reduces chickenpox.

Importance of neem in India

Neem has been used since time immemorial. Our ancestors without any high standard medical facilities and advanced technologies deemed to defeat all the health ailments by their sound and profound knowledge about trees and their medicinal properties. Many of us are still not aware about the vast importance of neem. It can be specifically used to cure each and every health ailment. In India, Neem is used for worshipping, has cultural significance, is considered as a symbol of heaven. There is a mythology hidden behind the curative properties of Neem. Moving to the export potential of Neem, India has not increased its export potential. But the global neem extract

ISSN : 2583-0910
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market is expected to grow rapidly, with a compound annual growth rate (CAGR) of 15.09% from 2024 to 2032. Brazil is currently the world's largest exporter of neem leaves.(N.I.I.R, 2003).

Value added products of neem

The value added products of neem includes neem facewash, neem shampoos, neem insecticides, herbal face packs, herbal lip Balms, neem moisturizing creams, neem soaps, neem powders and neem juices.

1. Neem Facewash

They are prepared by combining neem, aloe vera, aqua, glycerine and water. The above ingredients are mixed in proper proportions. Two parts of neem leaves grinded with little amount of water along with one part of aloe vera juice and one tablespoon of aqua with two parts of glycerine. This face wash purifies the skin, prevents acnes and pimples, removes dead cells and hydrates the skin.(Y.C., 2015).

Fig. 1 Neem face wash

2. Neem Shampoo

Neem shampoo is prepared by combining the neem leaves, rosemary herb, hibiscus leaves and flowers, fenugreek seeds and coconut water. The above ingredients are mixed in the proportion by combining two parts of neem leaves grinded, two parts of rosemary leaves boiled with the neem leaves and one part of hibiscus leaves and flowers. These are added to the coconut water. The fenugreek seeds are grinded and then mixed. This mixture is left overnight to settle down. This effectively prevents hair fall, dandruff, thickens hairs, removes split ends and reduces scalp thinning.

Fig. 2 Neem shampoo

3. Neem insecticides

Neem oil is a natural insecticide extracted from the seeds of the neem tree (*Azadirachta indica*). It is widely used in organic gardening to control pests due to its active compound, azadirachtin, which disrupts the growth and reproduction of insects. Neem oil works in multiple ways—it acts as a repellent, interferes with the moulting process of insects, and suffocates them when sprayed directly. It is effective against common garden pests such as aphids, whiteflies, mealybugs, spider mites, and caterpillars. To use neem oil as an insecticide, a simple spray can be prepared by mixing as per the required considerations and adding a few drops of liquid dish soap as an emulsifier. This solution should be sprayed on affected plants, especially on the undersides of leaves, every 7 to 14 days for prevention or every 3 to 5 days for active infestations. It is best applied in the early morning or evening to prevent leaf burn. Neem oil is safe for humans, pets, and beneficial insects like bees and ladybugs when used correctly, making it a popular choice for sustainable pest control.(G., 2017).

Fig. 3 Neem insecticides

4. Herbal Face Pack Using Neem: A Natural Solution for Clear and Glowing Skin

Neem, renowned for its antibacterial and anti-inflammatory properties,

is an excellent ingredient for a herbal face pack. Here's a simple DIY recipe to create a neem-based face pack. Its versatility shines in homemade face packs, like a blend with turmeric for acne-prone skin. Mix neem powder with turmeric and rosewater to create a soothing paste that fights acne and reduces inflammation. For oily skin, neem combined with multani mitti and lemon juice absorbs excess oil, tightens pores, and prevents breakouts, ensuring refreshed and healthy skin.

5. Neem herbal lip balm

Creating a herbal lip balm with neem and floral extracts offers a natural solution for nourished, protected lips. Neem's antibacterial and healing properties help prevent infections and chapping, while a base of coconut oil or shea butter provides deep hydration. Infusing floral extracts like lavender, rose, or chamomile enhances the balm with soothing, aromatic benefits—lavender relaxes, rose hydrates, and chamomile calms sensitive skin.

Fig.5.Neem lip balm

Once blended, the mixture is poured into containers to cool, resulting in a moisturizing balm that keeps lips soft, smooth, and protected from dryness.

6. Neem moisturizing creams

To make a neem-based moisturizer, begin by melting two tablespoons of shea butter or coconut oil in a double boiler until fully liquefied. Once melted, mix in two tablespoons of neem oil or neem leaf paste, along with four tablespoons of aloe vera gel and one tablespoon of glycerine. Stir the mixture thoroughly until it becomes smooth and well-blended. To enhance the fragrance and add therapeutic benefits, include a few drops of essential oil, such as lavender or tea tree.

Fig. 6. Neem moisturizing cream

Pour the prepared mixture into a sterilized container and allow it to cool and solidify. This neem moisturizer provides deep hydration, soothes irritation, and protects the skin from dryness and infections, making it an excellent choice for daily skincare.

7. Neem soap

To make Neem Soap, begin by gathering the necessary ingredients: neem oil (3 tablespoons), coconut oil (1 cup), olive oil (½ cup), shea butter (2 tablespoons), lye (4.5 ounces), distilled water (10 ounces), neem powder (1 tablespoon), and optional essential oils (10-15 drops) for fragrance. By preparing the lye solution: slowly add lye to distilled water stirring gently until fully dissolved. Allow the mixture to cool to about 100°F. In a separate heat-resistant bowl, melt the coconut oil and shea butter, then mix in the olive oil and neem oil. When the oils and lye solution reach similar temperatures (about 100°F), slowly combine the two. Blend the mixture with a stick blender until it reaches a pudding-like consistency, known as "**trace.**" Incorporate neem powder and essential oils, ensuring they are evenly distributed. Pour the mixture into silicone molds, tapping to remove air bubbles. Cover the molds with a towel and let the soap set for 24-48 hours.

Fig.7 Neem soap

Once firm, unmold the soap and allow it to cure in a cool, dry area for 4-6 weeks. This curing process enhances the soap's quality and longevity.

8. Neem juice:

To prepare neem juice, 1st 1 cup of fresh neem leaves thoroughly to remove any dirt or impurities. Blend the washed neem leaves with 2 cups of water until the mixture is smooth and the leaves are finely ground. Strain the blended mixture using a fine sieve or cheesecloth, pressing or squeezing to extract as much juice as possible, and discard the leftover pulp. For a less bitter taste, you can optionally add required quantities of lemon juice and honey. Once mixed, pour the neem juice into a glass and serve it fresh. For a refreshing option, refrigerate it briefly before serving. Neem juice is renowned for its detoxifying, antibacterial, and anti-inflammatory properties. Regular consumption can boost immunity, help manage blood sugar levels, and improve skin health.

Fig. 8 Neem juice

However, neem juice is very potent and should be consumed in moderation. Adults are recommended to take 1-2 tablespoons daily, diluted in water, or as advised by a healthcare professional. Excessive consumption should be avoided, and those who are pregnant, nursing, or have specific health concerns should consult a doctor before use. This natural remedy is a powerful addition to a healthy lifestyle but should be used responsibly.

9. Neem powder:

To make neem powder, start by harvesting fresh neem leaves, ensuring they are mature, green, and free from damage or pests. Wash the leaves thoroughly under running water to remove dirt or insects, and shake off excess water. Spread the washed leaves in a single layer on a clean tray, cloth, or mesh screen, and dry them in a shaded area with good airflow. Avoid direct sunlight, as it can reduce the neem's potency. Allow the leaves to dry completely, which may take 3–5 days, depending on humidity, until they become brittle and easy to crush. Once dried, crush the leaves into smaller pieces and grind them using a grinder, blender, or food processor until a fine powder is formed. Sift the powder through a fine mesh sieve if needed to remove larger particles. Store the neem powder in an airtight container in a cool, dry place away from sunlight. For faster drying, a dehydrator can be used. Ensure the leaves are completely dry to prevent mold growth. Neem powder is versatile and can be used in skincare, haircare, or as a natural remedy for plants.

Fig. 9 Neem powder

Conclusion

The study highlights the significant medicinal and therapeutic properties of neem and its potential as a natural alternative for disease management. Neem-based value-added products, such as soaps, shampoos, juices, and healthcare powders, offer holistic solutions for various health ailments, particularly diabetes, skin disorders, and hair problems. The formulation of these products integrates multiple herbal ingredients known for their anti-inflammatory, antibacterial, and anti-diabetic properties. The research underscores the growing need for natural, cost-effective alternatives to conventional treatments, especially for populations with limited access to medical care. While neem-based products may require consistent, long-term usage to yield noticeable effects, they offer a safer, sustainable approach to health management. Additionally, the global neem market presents substantial growth opportunities, indicating an increasing awareness and demand for natural remedies worldwide. Ultimately, neem's versatility and medicinal benefits make it an essential component in traditional and modern healthcare, reinforcing its importance in both domestic and global markets.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/02/0825

ADVANCES IN DRYING TECHNOLOGY FOR POST-HARVEST APPLICATIONS

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Introduction

One of the postharvest processing unit procedures that uses the most energy is drying. Following harvest, this unit operation is used to lower the water content of products such different fruits, vegetables, agricultural and herbal products, etc. The goal of lowering the water content is to increase the shelf life of bio-origin products by lowering the water activity to a point where enzymatic reactions, microbial development, and other deteriorative reactions are prevented. Before the active elements in some bio-origin goods, like herbs, can be removed, they must be dried. Additionally, the dried products weigh less, which lowers shipping expenses. The physical, chemical, and biological characteristics of the collected bio-origin products vary. To fulfil various quality and cost requirements, a wide range of dryers have been created to dehydrate and preserve these items. There are roughly 100 dryer varieties that are sold commercially, out of the more than 500 types that have been documented in the technical literature. The physical characteristics of the product, various heat input methods, variations in operating temperature and pressure, variations in the dried product's quality requirements, etc., all contribute to variations in dryer design. The majority of traditional dryers run at atmospheric pressure under constant drying conditions, use hot air as the drying medium, and employ convection as the only method of heat transfer. For obvious reasons, batch operation is favoured for devices with lesser capacities and longer drying times (such as solar dryers). The various technologies are summarised below:

Hybrid Heat Pump Drying with Programmable Thermal Input Modes

Heat pump dryers use low-temperature dehumidified air as the convective drying medium. Hence, drying in heat pump dryer can be carried out at relative low temperature as compared to conventional hot air dryers. This drying system incorporates a dehumidification cycle where condensation of dew allows the removal of water from the closed system of drying air circulation. A heat pump is used to perform condensation and heating of the dehumidified air. The heat pump recovers the sensible and latent heats by condensing moisture from the drying air. The recovered heat is recycled back to the dryer through heating of the dehumidified drying air. Heat pump drying of sapota pulp to produce sapota powder was reported to be faster than hot air drying (Jangam *et al.,* 2008). Drying of Australian nectarine slices in a heat pump dryer was found to produce the dried product that was better than that from cabinet and tunnel dryers in terms of lactone and terpenoid retention (Sunthonvit *et al.,*2007).

Intermittent Batch Drying

To lower running costs, such as heat input and power input, the operational condition of a drying process can be monitored by adjusting the airflow rate, temperature, humidity, or operating pressure separately or in combination. The goal is to maintain a high moisture removal rate while achieving great energy efficiency without pushing the product above its acceptable temperature and stress limits. Intermittent heat input profiles can be used in two different ways. The first one is to subject the drying materials to intermittent heat input, time-varying flow of drying medium or use of cyclically varying operating pressure in the drying chamber. The main purpose is to allow internal moisture to migrate to the material surface during non-active phase of drying, often termed the tempering period. Intermittent drying consists of two distinctive drying periods, namely, active drying and non-active drying. During active drying, heat input is applied by the drying medium, while during the non-active drying period, heat input or flow of the drying medium is stopped. The two distinctive periods are carried out in an alternating mode. Since water content on the surface is increased during the tempering period, the drying rate during the subsequent active drying is increased noticeably, which helps enhance the drying kinetics. However, since the rate of drying is finite during the passive period, the overall drying time is increased somewhat, but it is offset by the reduction in energy consumed and the better product quality due to lower product temperature. The second intermittent drying strategy is to apply stepwise change of operating conditions in order to minimize energy requirement. This is due to the fact that drying toward the end of the process is controlled by internal diffusion where the external factors have limited effect on the drying kinetics. As such, one possible way to reduce energy loss is to gradually reduce the heat input to the materials along the drying process. However, it should be noted that drying temperature at the final stage of drying cannot be too low as the equilibrium moisture content is dependent on temperature (Chong and Law 2009). One can also vary the mode of heat input (e.g., convection, conduction, radiation, infrared (Afzal 2003; King and Lin 2009), or microwave (Soysal *et al.,* 2009)/radio frequency heating). Multiple heat inputs can be used to remove both surface and internal moisture simultaneously. In this regard, Kowalski and Rajewska (2009) reported the use of microwave, infrared, and microwave–infrared coupled with convective drying which gave higher drying rates and reduced temperature gradient.

Modified Atmosphere Drying

To avoid oxidation of the drying material and destruction of its bioactive elements, hot drying air, which includes 21% of oxygen, can be replaced with nitrogen or carbon dioxide. By eliminating oxygen, oxidation and some unwanted reactions which require oxygen are thus prevented. This in turn reduces/eliminates browning of goods and enhances preservation of bioactive components. Furthermore, it has been reported that heat pump drying in a modified atmosphere raises the effective diffusivities of specific food items. Perera (2001) and O'Neill *et al*., (1998) have talked about the use of a heat pump in modified environment drying for specific food products. In their numerous experimental studies of modified heat pump drying on a variety of food goods, Hawlader *et al*., (2006) demonstrated a significant improvement in product quality, namely in terms of the retention of 6-gingerol in dehydrated sliced West Indian ginger.

Superheated Steam Drying

Superheated steam is an attractive drying medium for some processes since the net energy consumption can be minimized if the exhaust (also superheated steam) can be utilized elsewhere in the plant and hence is not charged to the dryer. Superheated steam does not include oxygen; hence, oxidative or combustion reactions are prevented. In addition, it also eliminates the possibility of fire and explosion threat. Superheated steam dryers typically produce goods of higher quality than traditional hot air dryers. Additionally, food products can be pasteurized, sterilized, and deodorized using superheated steam. Some products are not stable at 100 °C if the dryer operates at atmospheric pressure; one option to overcome this problem is to lower the operating pressure. This method has recently been tested on several goods, including porous medium (Tatemoto *et al.,* 2009) and chitosan film (Mayachiew and Devahastin 2008). At low steam pressures, drying rates are extremely low because convection still transfers heat. Low drying rates result in huge equipment sizes, which makes the process unpopular even if high quality can be obtained at low pressures.

Microwave Vacuum Drying

Microwave drying is typically combined with other drying methods to overcome the limitations of uneven heating resulted from focusing, corner and edge heating, inhomogeneous electromagnetic field, and irregular shape and non-uniform composition of material, for instance microwave freeze drying. Vacuum microwave has been tested as a pre drying method in the frying of food materials (Song *et al.,* 2007). Furthermore, its start-up costs are relatively high and it requires sophisticated mechanical and electronic components (Zhang *et al*.,2006). It has been demonstrated that microwave vacuum drying improves the texture and color of dried goods. Even during the first drying stage, heat can be transmitted to the material's inner core by volumetric heating made possible by microwave fields, which eliminates the differential requirement. Products that are vacuum and microwave dried have better color and texture than those that are air dried.

Osmotic Dehydration and Pretreatments

Thermal drying is an energy-intensive operation because it involves evaporation of water that requires vast amount of latent heat. Before the material is subjected to thermal drying and water removal by phase change, osmotic dehydration can be used to partially remove the liquid. The high latent heat of vaporization indicates that a significant amount of energy is used for the phase change; however, in osmotic treatment, some of the nutrients and color components may be lost to the osmotic agent. The osmotic solution must be concentrated in order to recover or recycle it. Applying evaporation, which uses a lot less energy than drying, can accomplish this. To improve the effectiveness of moisture transport, mechanical and chemical pretreatments can also be used either before or during heat drying. According to Germera *et al.,* (2009), recycling and reconditioning osmotic solution had no effect on the solid gain and water loss during peach drying.

Monitoring of Quality Attributes and Drying Parameters

Conventional drying system does not apply process control; thus, the system tends to encounter problems such as uneven product quality, over-dry, low energy efficiency, etc. In this regard, monitoring of product properties such as moisture content, product appearance such as color, and operating parameters such as temperature are some of the aspects one may consider to monitor during a drying process in order to enhance product quality or improve operating efficiency. Research and development in this aspect is rather scarce, and it remains a challenge to researchers in this area. It has been reported that:

- monitoring of product moisture content can be carried out using laser light backscattering imaging (Romano *et al.,*2008) or triboelectric probes (Portoghese *et al.,*2007).
- monitoring of surface water activity by controlling air relative humidity (Stawczyk *et al.,*2009) and monitoring of solvent residue in solvent drying (Tewari *et al.,*2009) can be achieved using near-infrared sensor.

- monitoring of the development of fracture in food material can be conducted using acoustic sensor (Kowalski and Mielniczuk 2006).

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ISSN : 2583-0910
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Article ID : 05/VIII/03/0825

CANNIBALISM IN NON-CARNIVOROUS INSECTS: A REVIEW OF EVOLUTIONARY ADAPTATIONS AND ECOLOGICAL IMPLICATIONS

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Abstract
Cannibalism, defined as the act of consuming a conspecific individual, is observed not only among carnivorous but also among non-carnivorous insects. In herbivorous insects, this practice often compensates for protein-deficient diets and emerges due to ecological stressors like overcrowding, starvation, or environmental instability. Unlike their carnivorous counterparts, non-carnivorous insects predominantly exhibit cannibalism during juvenile stages, frequently targeting eggs and larvae. This behavior has been observed across various insect orders including Lepidoptera, Coleoptera, Hemiptera and Orthoptera. Cannibalism provides several evolutionary advantages such as reduced competition, improved nutrition and population regulation. However, it also entails risks like disease transmission and loss of potential mates. This article reviews the causes, types, adaptive roles and ecological implications of cannibalism in non-carnivorous insects, along with directions for future research.

Keywords: *Conspecific, cannibalism, improved nutrition, potential mates and starvation*

Introduction

Cannibalism has long intrigued researchers due to its contradictory implications: it enhances survival and reproduction but simultaneously poses serious evolutionary risks. Though primarily documented in predatory species, cannibalism also appears among non-carnivorous insects. These behaviors are not random but are often triggered by ecological stressors, including limited food supply, high population density and competition for resources. Cannibalism serves as an alternative nutritional strategy, particularly in herbivorous insects that depend on low-protein plant matter.

Studies have recorded over 130 non-carnivorous insect species across multiple orders—including Lepidoptera, Coleoptera, Orthoptera, Diptera, Hemiptera, Blattodea and Hymenoptera—that engage in cannibalism at different developmental stages. These behaviors have evolutionary significance in population dynamics, nutrient recycling, and survival strategy optimization.

Ecological Triggers and Evolutionary Basis

Cannibalism in herbivorous insects is primarily influenced by two groups of factors:

- **Density-dependent**: Includes competition for food and space, leading to increased encounter rates among conspecifics.

- **Density-independent**: Includes environmental variables like temperature, humidity, and food quality.

From an evolutionary standpoint, cannibalism enhances individual fitness by offering high-protein nutrition that supports rapid development and increased fecundity. It may also reduce the prevalence of diseases and parasites by eliminating weakened or infected conspecifics. Insects often consume smaller or vulnerable individuals such as eggs, moulting juveniles, or larvae, thereby minimizing risk to the cannibal while maximizing benefits.

Cannibalistic Orders of Non-Carnivorous Insects:

Table 1: Insect orders and families

SL.NO	ORDER	FAMILY
1.	Orthoptera	Acrididae, Gryllotalpidae, Tettigoniidae
2.	Blattodea	Blaberidae, Blattellidae, Blattidae
3.	Hemiptera	Cydnidae, Lygaeidae, Miridae, Pentatomidae, Rhopalidae
4.	Coleoptera	Bostrychidae, Bruchidae, Buprestidae, Cerambycidae, Chrysomelidae, Coccinellidae, Cucujidae, Curculionidae, Dermestidae, Elmidae, Nitidulidae, Scolytidae, Silphidae, Tenebrionidae
5.	Hymenoptera	Cephidae, Megachilidae
6.	Lepidoptera	Arctiidae, Dalceridae, Galleriidae, Gracillariidae, Lithocolletidae, Lycaenidae, Noctuidae,Nymphalidae, Papilionidae, Phalaenidae, Pieridae, Prodoxidae, Pyralidae, Sesiidae, Tortricidae
7.	Diptera	Agromyzidae, Muscidae, Psychodidae, Simuliidae

Occurrence Across Insect Orders

Lepidoptera: Larvae of the bella moth (*Utetheisa ornatrix*) consume conspecifics to obtain alkaloids necessary for their defense and mating success. Similarly, monarch butterfly larvae destroy nearby eggs post-hatching.

Coleoptera: Species like the willow leaf beetle (*Plagiodera versicolora*) exhibit cannibalism within 24 hours of hatching, especially when kin recognition is absent.

Hemiptera: Nymphs of the small milkweed bug (*Lygaeus kalmii*) practice egg cannibalism, particularly during vulnerable developmental phases.

Orthoptera: Grasshoppers such as *Spathosternum prasiniferum* show cannibalistic tendencies under high temperature and low humidity conditions.

Diptera: Larvae of *Agromyza frontella* reduce cannibalism through pheromonal deterrents released by ovipositing females.

Blattodea and Hymenoptera: In cockroaches (*Periplaneta americana*), females consume males post-mating. Some hymenopteran larvae, such as those of the wheat stem sawfly (*Cephus pygmaeus*), consume eggs or competitors to boost their survival chances.

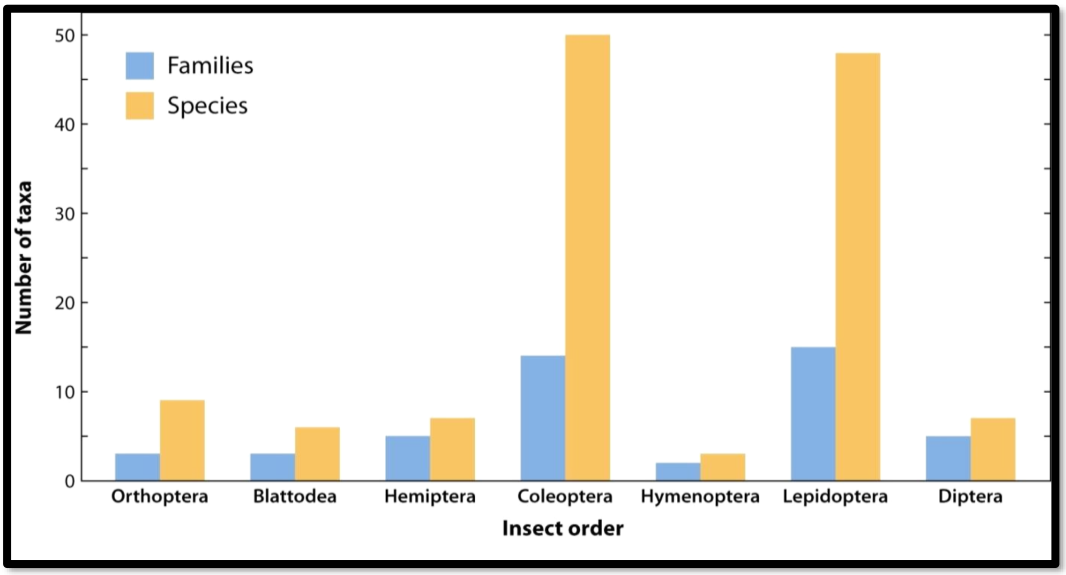

Figure 1. Number of insect families and species of seven orders for which cannibalism has been reported in insects that typically are not carnivorous (Richardson *et al*., 2010)

Types of Cannibalism in Insects

Cannibalistic behavior in non-carnivorous insects can take various forms:

1. **Infanticide and Ovicide**: Adults consume eggs or larvae to enhance their own progeny's survival chances.
2. **Sexual Cannibalism**: Common in mantids and some Lepidoptera, where females eat males during or after copulation, gaining nutritional benefits.
3. **Autophagy (Self-cannibalism)**: Insects like *Drosophila melanogaster* use self-digestion to survive starvation or during metamorphosis.
4. **Trophic Egg Production**: Seen in beetles and some hymenopterans, females lay unfertilized, nutrient-rich eggs as a food source for offspring.

Advantages

- Improves access to protein-rich food.
- Enhances growth, fecundity, and competitive ability.
- Reduces intraspecific competition.
- Controls population density and removes diseased individuals.

Disadvantages

- Risk of pathogen transfer.
- Loss of reproductive potential if mates are consumed.
- Potential reduction in genetic diversity.
- May lead to behavioral maladaptations in densely populated systems.

Behavioral and Environmental Modulation

Cannibalism is not always a default behavior. Several adaptations help insects regulate or suppress it. For instance, Mormon crickets form migratory bands to reduce chances of intra-group cannibalism. Larvae in some Diptera leave behind chemical cues to deter others from cannibalizing the same area. Environmental influences like availability of genetically modified crops (e.g., *Bt-*

corn) also alter cannibalism frequency due to reduced food quality, as seen in *Helicoverpa zea* larvae.

Future Research Perspectives

Understanding cannibalism's full implications in insect ecology requires interdisciplinary focus. Key future directions include:

- Genetic and molecular control mechanisms.
- Behavioral distinctions between cannibal and non-cannibal individuals.
- Impact of agroecological practices on cannibalism frequency.
- Role in pest outbreak regulation and resistance evolution.
- Cross-species studies to develop broader ecological models.

Conclusion

Cannibalism in non-carnivorous insects is an adaptive trait rooted in ecological necessity and evolutionary pressure. It serves as a survival strategy under resource constraints, regulating population dynamics and enhancing individual performance. However, the behavior also introduces risks that must be weighed against its benefits. Given its prevalence and complexity, further research is crucial for its integration into ecological theory and pest management strategies.

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ISSN : 2583-0910
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Article ID : 05/VIII/04/0825

AI: THE SILENT RESEARCH PARTNER OF TODAY'S RESEARCH SCHOLARS

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Introduction

Artificial Intelligence has rapidly become a transformative force in academic research, fundamentally reshaping the landscape of scholarly inquiry. Once the exclusive domain of computer science, AI has quietly but powerfully extended its reach across virtually every discipline from medicine and engineering to the social sciences and humanities. Today, AI acts as a silent partner for research scholars, automating labor-intensive tasks, accelerating the pace of discovery, and enhancing the depth and breadth of analysis. Its ability to sift through vast volumes of data, identify patterns, and generate insights has elevated the efficiency and impact of research to unprecedented levels. As AI tools become more sophisticated and accessible, they are not only changing how knowledge is discovered, analyzed, and communicated, but also redefining the very nature of collaboration and innovation in academia. This article explores the evolving role of AI as the "silent research partner," highlighting its transformative impact, key applications across the research workflow, the ethical considerations it raises, and the exciting future it promises for research scholars worldwide.

The Evolving Role of AI in Research

Traditionally, research involved laborious literature reviews, manual data analysis, and iterative writing, but today, AI tools streamline nearly every stage of the research workflow. Unlike overt collaborators, AI often works in the background suggesting relevant papers, summarizing findings, detecting patterns, and even checking for plagiarism making it a "silent partner" that significantly boosts productivity and insight (Khalifa, 2024; Lo, 2023). Researchers now increasingly rely on AI-powered platforms for tasks that once consumed substantial time and mental energy. Rather than replacing human intellect or creativity, these tools amplify them, enabling scholars to focus on higher-order thinking, hypothesis generation, and critical analysis (Lo, 2023; Madanchian, 2025).

Key Areas Where AI Supports Research Scholars

Literature Review and Knowledge Discovery

AI-driven platforms can scan millions of academic papers, extract key findings, and synthesize literature reviews in minutes, enabling researchers to identify gaps and emerging trends through semantic analysis, summarize dense academic texts, and visualize connections between studies and authors to facilitate interdisciplinary discovery (Khalifa, 2024; Májovský *et al.,* 2023). Automated citation generators and reference managers streamline the process of organizing sources, ensuring accuracy and adherence to style guidelines. Tools like Scholarcy and Jenni AI extract references and organize content systematically, reducing the risk of oversight (Švab *et al.,* 2023; Zhou *et al.,* 2025).

Data Collection and Analysis

AI excels at handling large, complex datasets whether quantitative or qualitative by leveraging machine learning algorithms that can detect patterns, correlations, and anomalies in data that might elude human analysts. These algorithms automate statistical analysis and predictive modeling, and are capable of interpreting unstructured data such as interview transcripts or social media posts through natural language processing (Madanchian, 2025; Lo, 2023). Additionally, AI-powered visualization tools transform raw data into accessible graphs, charts, and infographics, making complex findings understandable at a glance (Khalifa, 2024).

Figure 1. Depiction of Future Fields: AI and Agri-Science Synergy

Writing and Publication

AI writing assistants have become invaluable tools for researchers by not only suggesting the overall structure and content flow of academic papers but also by meticulously checking grammar, style, and clarity to enhance readability and coherence. These tools can detect plagiarism, ensuring the originality and integrity of scholarly work, which is crucial in maintaining academic standards (Dergaa *et al.,* 2023; Khalifa, 2024). Beyond writing support, AI also streamlines the often complex publication process by helping scholars track manuscript submissions, monitor peer review feedback, and generate concise, impactful abstracts. This automation reduces administrative burdens and accelerates the path from manuscript preparation to publication, allowing researchers to focus more on their core scientific contributions (Švab *et al.,* 2023).

Collaboration and Communication

AI is also transforming collaboration and communication in research environments. AI-driven project management platforms help coordinate tasks, set deadlines, and track progress, significantly reducing the administrative burdens faced by research teams (Lo, 2023). Language translation tools powered by AI break down barriers, making research findings and collaborations more accessible to a global audience, while text-to-speech and speech-to-text technologies further enhance accessibility for scholars with disabilities (Khalifa, 2024). Additionally, AI chatbots and virtual research assistants manage routine queries, schedule meetings, and handle administrative questions, freeing up researchers to concentrate on more substantive and creative aspects of their work (Lo, 2023).

Ethical Considerations and Challenges

The integration of AI into academic research brings with it a host of ethical considerations and challenges that scholars must navigate thoughtfully. One major concern is bias and transparency, as AI systems are only as reliable as the data on which they are trained; if datasets are biased or unrepresentative, AI can perpetuate and even amplify existing inequalities, making it essential to use diverse and representative training data, conduct regular audits for discriminatory patterns, and employ transparent, explainable algorithms (Meyer *et al.,* 2023; Khalifa, 2024). Data privacy and security also come to the forefront, since AI often processes sensitive information, raising important questions about privacy and consent that require robust data governance frameworks, privacy-preserving techniques, and clear documentation to protect individual rights (Madanchian, 2025). Despite the automation that AI offers, human oversight and accountability remain crucial especially in high-stakes research contexts. So, scholars must critically evaluate AI-generated outputs, uphold research integrity and ethical compliance, and ensure that AI serves to augment rather than replace human judgment (Dergaa *et al.,* 2023). Finally, there is the risk of over-reliance on AI tools, which may erode foundational research skills and critical thinking if not balanced with traditional scholarly rigor, researchers must therefore remain vigilant, using AI as a tool to support, not supplant, their expertise (Májovský *et al.,* 2023).

The Future of AI as a Research Partner

The future of AI as a research partner is poised to be even more transformative, with emerging generative AI models now capable of generating hypotheses, designing experiments, and even drafting entire research papers. The next frontier involves autonomous research agents that can independently conduct literature reviews, analyze data, and propose new research directions with minimal human intervention, potentially revolutionizing the pace and scope of scientific discovery. As these technologies advance, tomorrow's researchers will need to develop new skill sets, including technical proficiency in using and evaluating AI tools, critical thinking to assess AI-generated insights, and ethical literacy to navigate complex challenges related to bias, privacy, and accountability (Khalifa, 2024). To fully realize the promise of AI in research, its integration must be guided by principles of transparency, fairness, and responsibility, with institutions, publishers, and scholars working collaboratively to establish standards and best practices for ethical AI use (Meyer *et al.,* 2023).

Conclusion

In conclusion, AI has quietly become the indispensable research partner that today's scholars rely on to navigate the ever-growing complexities of academic work. From speeding up literature reviews and data analysis to assisting with writing and collaboration, AI tools are transforming research into a faster, more efficient, and more insightful process. However, as AI continues to evolve and take on more sophisticated roles, it also brings important ethical challenges that researchers must address, including bias, privacy, and the need for human oversight. Embracing AI as a powerful ally not a replacement allows scholars to focus on creativity, critical thinking, and innovation, ultimately pushing the boundaries of knowledge further than ever before. The future of research is a partnership between human intellect and artificial intelligence, working silently together to unlock new discoveries and shape a better world.

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ISSN : 2583-0910
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Article ID : 05/VIII/05/0825

COMMON MEDICATIONS AND DISEASE CONTROL IN HOME AQUARIUM TANKS

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1. Ulcer

Cause : Caused by *Pseudomonas* and *Aeromonas* bacteria

Treatment : Fish lose salts quickly through open wounds, so add aquarium salt at a dose of 1-3g/litre.

2. Cloudy eye

Cause: Caused by poor water quality, poor diet, eye flukes, corneal damage, bacterial

Treatment: Improve water conditions. Use a good quality food containing added vitamins.

3. Dropsy

Cause : Usually caused by bacterial infection. Viral infection, utritional, metabolic and Osmoregulatory problems can also be responsible

Treatment : Improve water conditions immediately. Aquarium salt at a dose of 1- 3g/litre can help to prevent salt loss.

4. White spot

Cause: Caused by *Ichthyophthirius multifiliis* parasite

Treatment: Treat promptly with an antiparasite medication. It may be necessary to raise the water temperature to improve the effectiveness of the treatment.

5. Bacterial infection

Cause: Caused by *Aeromonas* and *Pseudomonas* bacteria

Treatment: Use a proprietary treatment as soon as possible. Aquarium salt at a dose of 1- 3g/litre can help prevent salt loss.

6. Fungus

Cause: Caused by *Saprolegnia* and *Achlya*

Treatment: Standard antifungal medications, such as methylene blue, are usually very effective, but may affect filtration and water quality. When the disease occurs on open wounds, aquarium salt at a dose of 1- 3g/l can help reduce salt loss

7. Finrot

Cause: Caused by *Aeromonas*, *Pseudomonas* or *Flexibacter* bacteria

Treatment: Improve water conditions. Isolate nippy fishes. adding salt (1-3g/litre) to reduce the loss of salt by the fish. Ensure that water stays free of pollution during treatment.

8. Swimbladder disorder

Cause: Caused by bacterial infection, incorrect diet, trapped gas, physical deformities.

Treatment: Change diet and Improve water conditions. Feed less dried foods, or pre-soak pellets and flakes so they don't swell the gut. Feed *Daphnia*, which acts as a laxative. Treat with a specialist antibacterial.

9. Velvet (Gold Dust Disease)

Cause: Caused by a species called Oodinium, attach itself to fish's skin and gills. destroying the cells and feeding off of the nutrients inside. Also known as 'Rust', it's a common disease in aquarium fish, and has the potential to kill every inhabitant in your tank.

Treatment: Common medications used include copper sulfate, methylene blue, formalin, malachite green, and acriflavin.

10. Cotton Fin Fungus

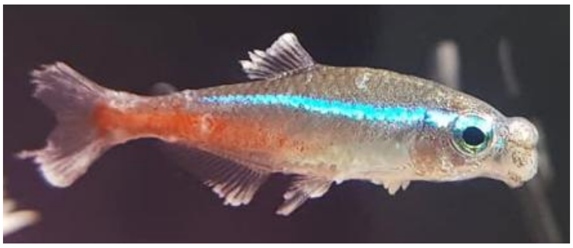
Cause: known as Cotton Wool Disease, it's a condition that typically affects aquarium fish with weak immune systems. Characterized by the cotton wool growths, it's fairly common and it's important to address this immediately before it can cause a lot of damage.

Treatment: Salt, Methylene blue and Malachite green. Malachite green is readily available and is known to be effective. add aquarium salt to tank at a low level of 1-3 grams per litre.

11. Neon Tetra Disease

Cause: bacterial infections caused by a parasite which enters the fish, invading the stomach and digestive tract consuming the fish from the inside out. Parasitic organism known as *Pleistophora Hyphessobryconis*, it feeds on the fish until it dies.

Treatment: No medicine or treatment for infected fish, should remove the infected fish and to take safety measures maintaining high-quality water levels and regular cleaning.



12. Columnaris (Mouth Fungus)

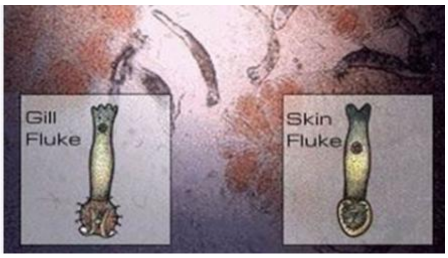
Cause: Fungal infection (Cotton Fin) due to its mold-like lesions, this is a common bacterial infection in aquarium fish. Columnaris is common where high bioloads or stressful conditions exist. These can be due to overcrowding, injury, inadequate diet, poor water quality, and unstable pH.

Treatment: The disease does not survive in salt solutions of 1% or higher. So salt can be a great initial treatment if the case is less severe. Antibiotic Oxytetracycline is treats gram-negative bacterial infections. Its very effective option.

13. Flukes (Skin And Gills)

Cause: Flukes are commonly present in aquariums, however, they'll remain harmless under favorable conditions.

Treatment: Treat with Praziquantel. This is an anti-worm medication which prevents Flukes and treats infections. A huge advantage of is medicine is that it's harmless to all species, not toxic to plants, and has no negative impact on aquarium filters.



Control Measures

- ✓ Prevention is the best form of Medicine
- ✓ Nutritious diet
- ✓ No dramatic temperature changes
- ✓ High water quality
- ✓ Observation of tank
- ✓ Quarantine

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/06/0825

UNLOCKING THE BENEFITS OF BIOCHAR FOR SUSTAINABLE SOIL IMPROVEMENT

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Abstract

Soil degradation can be caused by natural or man-made factors, and it can significantly affect social issues, political aspects of human civilization, environmental quality, and agricultural sustainability. Degraded soil can be restored by applying biochar to increase soil quality, encouraging better land use systems, conservation management techniques, etc. In order to determine that the use of biochar is a promising alternative capacity and porosity and lowered bulk density, as well as having the ability to serve as a microhabitat for soil microorganisms, we must examine changes in the attributes of soils amended with this product in this article. Nevertheless, the impact on greenhouse gas emissions remains unclear, with inconsistent outcomes based on agricultural systems and soil types. Biochar has a higher pH value so that it is used to treat acidic soil and reduce soil N_2O emission. Biochar has good sorption property, which helps in retaining N compounds such as NH_4^+ and NO_3^-; which positively affect N cycle in the soil.

Keywords : biochar, soil degradation, sustainability, greenhouse gas emission, bulk density

Introduction

The term 'biochar' refers to black carbon formed by pyrolysis of biomass by heating it into oxygen-free environment such that it doesn't combust or combust partially. One proven method for improving soil carbon sequestration and reducing climate change is the application of stable carbon in the form of biochar to agricultural soils (Mekuria and Noble, 2013). Some biochars' capacity to lower soil GHG emissions (CO_2, CH_4, and N_2O) has further demonstrated how crucial they are to addressing climate change. In general, biochars raise soil CO_2 emissions, decrease N_2O emissions, increase water holding capacity of soil and have variable impacts on CH_4 emissions (Case et al., 2012; Jeffery et al., 2016). However, the feedstock, pyrolysis condition, and other factors determine the direction and strength of the effects on GHG emissions. In order to develop a useful new material, biochar is frequently made from biomass and solid waste materials, including sludge, animal and poultry manure, and agricultural and forestry leftovers. Biochar's use has spread throughout the world due to its capacity to remove pollutants, lower greenhouse gas emissions, and clean up contaminated soil (Nandi *et al.,* 2024).

Biochar efficiently absorbs between 1 and 35 gigatons ($GtCO_2$) of CO_2 annually, and between 78 and 477 $GtCO_2$ this century. By storing carbon in the soil for long periods of time and so lowering greenhouse gas emissions, biochar helps slow down global warming (Nandi *et al.,* 2024). Higher crop yields are encouraged by this improvement in soil fertility, water retention capacity, and nutrient circulation. Biochar treatment at a rate of 100t/ha resulted in the greatest favorable results (39%). Additional benefits were observed in pH-neutral soils (13%), acidic soils (14%), and soils with a coarse (10%) or 13% for medium texture. This implies that a liming effect and an impact on the soil's ability to retain water may be two of the primary mechanisms for increasing output (Jeffery *et al.,* 2011). The particular soil type and crop management determine the ideal rate of biochar application.

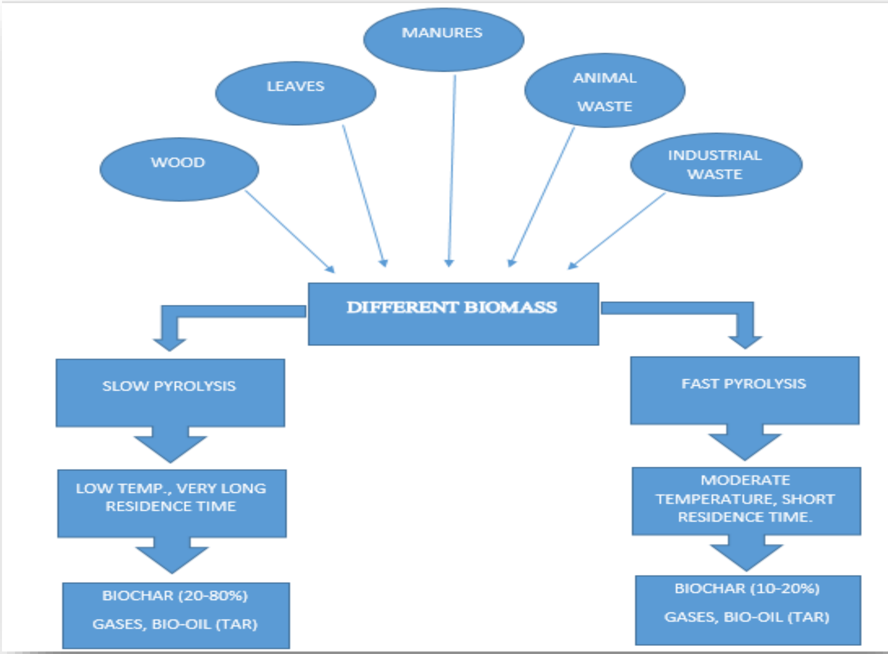

Figure 1: Biochar from different biomass (Rawat *et al*., 2019)

Biochar application in agriculture and its effects on global carbon cycle

Biochar is a stable, carbon-rich, porous material that resembles charcoal. It has a large, suitable surface area, high porosity, and a great ability to absorb different pollutants, such as heavy metals (HMs) (Ahmad *et al.,* 2012). The pyrolysis process reduces the volatile gases, preventing oxidation and extending the biochar's shelf life. As a result, microorganisms cannot break down biochar when it is added to the soil. Rather the biochar sequestrates CO_2 and being resistant to degrade biochar could capture carbon for a long time. Because of their physiochemical qualities biochar can capture carbon for an extended duration (Li and Chan, 2022). Carbon sequestration is aided by the high carbon content, thermal stability, and recalcitrant aromatic carbon structure of biochar (Nandi *et al.,* 2024). Biochar plays an important role in removing heavy metals and other pollutants from soil. Biochar can also enhance soil fertility, promoting plant development by influencing their root systems and aiding plants in absorbing and converting carbon dioxide (CO_2) (Rawat *et al*., 2019). During composting, biochar can lower nutrient losses and boost microbial activity. During this process, the biochar's mobile matter content breaks down into plant nutrients, it becomes "charged" with nutrients, covered with microorganisms, and its pH is regulated. Although mobile matter is very vulnerable to biological decomposition, which can counteract those benefits, it can also hinder porosity and early adsorption. There is no denying that biochar offers a number of benefits for agricultural management. The advantages of biochar are numerous. However, there are some disadvantages. Crop production and soil quality suffer when biochar is used insufficiently (Hussain *et al.,* 2017).

In general, alkaline, pH and the mineral components of biochar (ash content, as well as N, P, K, and trace elements) can offer significant agronomic benefits to many soils, at least in the short to medium term. The addition of biochar to the soil has demonstrated an increase in the availability of basic cations as well as in the amounts of phosphorus and total nitrogen (Glaser *et al.,* 2002). Similar to the other properties, the pH of biochar is affected by the type of feedstock, production temperature, and processing time frame (Rawat *et al*., 2019). Generally speaking, the amended soil became less acidic when biochar with a higher pH value was applied to it; however, acidic biochar may also raise the pH of the soil when used in soil with a lower pH value (Yuan *et al.,* 2011). With an average pH of 8.6, biochar has a high pH overall; which decreases soil N_2O emission. Biochar functions as a liming agent when added to acidic soil. For instance, using biochar rather of calcium oxide, which can react with $2H^+$ to form H_2O and CO_2, may be beneficial (Brassard *et al.,* 2016).

Indeed, research in both tropical and temperate climates has shown that biochar can boost plant growth, decrease nutrient leaching, increase water retention, and boost microbial activity. In a study conducted on a Colombian Oxisol (a soil type that is also widely found in Hawaii), the total biomass of plants above ground increased by 189% when biochar was applied at a rate of 23.2 tons per hectare. It also shows that biochar applications improve beneficial mycorrhizal relationships and biological nitrogen fixation in common beans (Phaseolus vulgaris). In Brazil, the occurrence of native plant species increased by 63% in areas where biochar was applied. Finally, studies have shown that the properties of biochar that are most crucial to plant growth can improve over time after it is incorporated into soil (Hunt *et al.,* 2010).

Biochar in sustainable development

Because it solves a number of environmental, financial, and social issues, biochar—a carbon-rich substance made by thermally breaking down biomass in an oxygen-limited environment—is essential to sustainable development. By storing carbon in a stable form, limiting its release into the atmosphere as carbon dioxide, and generating renewable energy byproducts like syngas and bio-oil throughout its production process, it makes a substantial contribution to mitigating the effects of climate change. Biochar also boosts soil health and promotes sustainable agriculture by boosting soil fertility, water retention, and microbial activity while lowering the need for chemical fertilizers, making it particularly important for rehabilitating degraded lands and assisting small-scale farmers. Additionally, by turning organic waste materials—such as agricultural residues and urban green waste—into value-added products, biochar production provides a sustainable solution to waste management. This aligns with the circular economy's tenets and addresses pollution through soil and water remediation. Its high adsorption capacity makes it useful for filtering water, eliminating impurities like nitrogen compounds and heavy metals, raising water quality, and preserving water resources in arid areas by increasing the soil's ability to store water. Furthermore, the production of biochar helps to meet energy needs and improve economic feasibility while also promoting green jobs and renewable energy generation, especially in rural and impoverished areas.

Clean water and Sanitation: Biochar is an underappreciated method of purifying drinking water because of its remarkable ability to extract different pollutants from liquid solutions. When compared to conventional low-cost techniques (such sand filtration, heating, solar chlorination, and disinfection), the treatment might have clear benefits. Current techniques use boiling and other processes that result in hazardous chemicals like chloroform. Nevertheless, biochar preserves the water's sensory qualities without endangering its security.

Greenhouse gas mitigation: There is an urgent need to investigate sustainable and reasonably priced technologies to lower GHG output and encourage soil carbon absorption due to the sharp rise in GHG emissions over the past few decades. the main factors that can make biochar less successful at reducing greenhouse gas emissions. Because of its high carbon content, biochar has a considerable ability to store carbon in soil, particularly when the oxygen to carbon ratio is less than 0.2. Additionally, it has active functional groups and aromatic structures that prevent it from breaking down in soil.

Affordable clean energy: Materials made of biochar have been used as anodic materials for sodium-ion dry cells and fuel in experimental settings. Commercial lithium-ion batteries use graphite as an anode material. These biochar and carbon nanomaterials' shape and nanostructure make them appealing anodes for enhancing electrochemical performance by altering surface properties, such as porosity, and adding microscopic variations. Furthermore, the non-faradaic charge storage in lithium-ion and sodium-ion batteries is changed when heteroatoms are added to biochar.

Good health and well-being: Biochar is a substance that provides essential nutrients and increases the ability of soil to support life. The impact of biochar additions on soil nutrient levels varies. By raising nutrient concentrations, lowering PTE levels, and enhancing production, biochar provides both direct and indirect benefits. It has been shown that using Biochar, a substance that may remove harmful, dangerous substances, to treat soil can significantly reduce the health risks associated with eating vegetable tables grown in that soil. Indicators including the average daily intake (ADI), the target risk of cancer (TCR), and the target risk quotient (THQ) are used to quantify this risk decrease.

Elimination of poverty and hunger: By improving soil fertility and quality, reducing dependency on inputs, and boosting revenues, the use of biochar in sustainable land management helps to reduce poverty. Producers are encouraged to increase profitability through sustainable practices. As attempts to reduce poverty advance, biochar systems can help the environment in light of climate change.

Conclusion

Several factors, like as feedstock and pyrolysis temperature, application, and others, can affect how plants and soil react to the addition of biochar, rate, technique, and application context (soil type, crop, and biological and environmental stressors). Biochar has the ability to generate renewable energy from farms in an environmentally responsible manner. In particular, the type of soil, metal, and carbonization raw material, the pyrolysis conditions, and the quantity of biochar added to the soil all affect the quality of the biochar. It is not unexpected that studies show a wide variety of reactions to the application of biochar’s given their heterogeneous nature and the complexity of the physical, biochemical, and microbiological mechanisms underlying their impacts. The long-term efficacy of biochar soil applications to reduce GHG emissions is an important area for future research. There is growing evidence that biochar ages after field application, resulting in a reduced or reversed priming effect. Over time, biochar acidification, mineral dissolution, and dissolved organic carbon release also change the rhizosphere's microbial communities, causing unpredictable GHG flux from soil to the atmosphere.

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Article ID : 05/VIII/07/0825

BEST MANAGEMENT PRACTICES IN SHRIMP FARMING

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Abstract

Aquaculture plays a crucial role in production of food and employment generation as well as the economy growth of any country. Due to high production cost and low demand in global shrimp market farmers now facing the problems, if we employed Better management practices (BMPs) we can reduce the problems related to production cost. Here, in this article we discussed about Better management practices in shrimp farm, from pond preparation to selection of seed, water screening, biosecurity, water quality management, and feed management, management of pond bottom, health and disease management and good harvest practices. Using these BMPs will improve the productivity, and profitability, also gives the better output. Adopting these BMPs in shrimp farm is mainly focused on the sustainable aquaculture to save the environment and biodiversity for that we have to use probiotics instead of using antibiotics, managing the effluents and also water before they were released into the environment like rivers, and canals to maintain the spreading of the diseases and to reduce the contamination.

Key words: Best management practices, Diseases, Effluent, Feed**,** Water quality

Introduction

Aquaculture is one of the fastest growing industry which provides protein food for the people. During last decades, the uses of excess amount of antibiotics in order to control the diseases also discharged the effluents without treatment into the open environment. If this is continuing leads to damage of environment also effects the aquaculture production for maintaining this, farmers to follow the Better management practices, to obtain sustainable aquaculture. Sustainable aquaculture can be defined as an aquaculture production system that uses renewable resources as much as possible, operates in balance with the environment and other living systems, and gives the animals living conditions that are as similar to those of their natural habitats. Adopting the BMPs may help in achieving the sustainability.

Best management practices

Best management practices (BMPs) in aquaculture focus on sustainable and responsible farming techniques to minimize environmental impact and improve production efficiency. These practices encompass various aspects, including water quality management, feed management, disease prevention, and waste management. The Best management practices encompass social responsibility, legal compliance, thoughtful site selection and farm building, as well as appropriate management procedures from pond preparation to harvest and post-harvest operations. Adopting BMPs would lead to increased output, returns, and productivity while also assuming social and environmental obligations. The main objective of BMP development is to assist farmers in managing their facilities more financially and effectively while adhering to rules regarding wastewater discharge. Environmental Protection Agency (EPA) of the United States acknowledges best management practices (BMPs) as “schedules of activities, maintenance procedures, prohibitions of practices and other management practices to prevent or reduce the pollution of water of the United States”.

Guidelines for Best management practices in shrimp farming

- Increasing demand for the shrimp products is leading to high stocking densities and usage of more chemicals in the aquaculture sector. If the process continued, aquaculture will be dropped into an unsustainable condition. BMPs are the only approach to overcome the problems.
- BMP can be defined as a set of guidelines that are developed, based on risk factor studies, in consultation with the practitioners and relevant stakeholders on the evaluation of current issues. Production should be increased to meet the demand; at the same time, we should keep sustainability in mind. BMPs should be simple, science based, cost- effective and appropriate to their context if farmers are to adopt and implement them. Some important BMPs steps.

Preparation of pond bottom

Pond bottom preparation is one of the major steps in shrimp and fish farming, while preparing the ponds we should follow these;

- Increasing the water holding capacity of pond.
- Completely drain the water from the culture pond.
- Remove the sludge and other organic wastes from the pond bottom.

Sludge must be removed from the culture pond when there is less gap between two crops, because sludge control is very crucial. During the culture periods uneaten feed, dead animals, dead planktons and all other settled matter at the bottom will remain as sludge. Both organic and inorganic materials present in this sludge, which will promote the growth of pathogens and also an algalblooms. By using pond vacuums, sludge can be removed. We should be more careful that no rainwater does not re-enter the pond with organic debris that has been removed. The pond should be left for drying up to 20-25 days under the sun, or until the soil gets cracking. After drying, ploughing is done to reduce the turbidity and leakage. Liming of pond bottom is the process of fertilization of pond to improve soil fertility and pond carrying capacity. Application of vermi compost 500-1000 kg/ ha or manure @ 500-2000kg/ha. Before applying the lime we have to check the pH of the soil, if pH is 7 i.e., neutral then there is no need to apply the lime, if soil pH is less than 7 then lime application is needed @50kg/ha of burnt lime or quick lime (CaO) and agricultural lime @100kg/ha for increasing the pH of soil and maintaining the pH , buffering capacity of soil.

Fig.1. Drained pond

Fig.2. Liming of pond bottom

Treatment and screening of water:

In order to control the spreading of diseases in culture pond, water screening is required. If water screening is done properly then there is no need to apply disinfectants. Three- stage water filtration is used to prevent the entry of particulate matter through water. First inlet water is filtered through a 150 microns mesh screen, and then water is settled for 2-4 days to remove the settled matter. After that, water is treated with 25 ppm of bleaching powder and 5 ppm of potassium permanganate to eradicate the bacteria and some other parasites.

Selection of post larvae and stocking:

This is one of the most crucial elements that effects the entire crop.

- Selection of seed or post larvae which are SPF i.e., specific pathogen free from the hatchery which is certified by coastal aquaculture authority (CAA).
- Uniform size and shaped post larvae should be selected.
- The post larvae should actively swim against the water current.
- Avoid wild seed because they may carry some harmful pathogens.
- Pack the seeds in such a way that it should contain adequate amount of aeration and a good amount of artemia. So that seed can be transported for the destination site.
- For *P.monodon* PL 20 and *L. vennamei* PL 13 are the required sizes.
- Pond water should be in green color, before the seed is ready to release into the pond.
- We have to acclimatize the seed in order to reduce the stress in the post larvae.
- Low temperature times i.e., early morning and late evening is best time for releasing the seed into the pond.

Fig.3 Acclimatization of seed

Fig.4. Packing of post larvae

Biosecurity:

Biosecurity refers to the precautions taken to keep particular pathogens out of shrimp cultures. In shrimp farming, biosecurity includes sanitation, personal hygiene, pond preparation, water screening, disease – free seed stocking, and the prevention of disease carriers from entering the area. In order to maintain a disease- free environment, biosecurity is essential in farming.

- Use crab fencing because they carry the pathogens.
- Use bird fencing to avoid the bird droppings.
- Maintain the farming area by sanitation dips like Potassium permanganate solution at entry and exit areas.
- Clean farming tools and materials with $KMnO_4$ to avoid cross contamination.
- Farm workers should maintain personal hygiene.

Feed management:

As feed management requires about 50-60% of overall expenses, it is most essential part of effective shrimp production.

- Provide fresh, high quality feed to the shrimp.
- Feeding should start from 1st day of stocking. Starting with 2 kg feed per day per 1,00,000PL and after 300 grams increase every day until 30 days this is called blind feeding.
- After 30 days, feed given based on body weight and check tray observation.
- By checking the check tray, we can increase or decrease the feeding rate.
- We should monitor the ammonia and nitrate conditions regularly.
- Regular sampling is done for checking the growth, survival and FCR of the shrimp.
- Avoid over feeding as it leads to formation of sludge and increases the toxic substances in water.

Water quality management:

To get good production and high yield, it is more crucial to maintain the water quality of pond. This factor will influence the entire culture, so we have to maintain the water clean.

- Frequently exchanging the water should be avoided .
- Maintain a reservoir for water treatment before releasing into the culture pond.
- For treatment, use high quality bleaching powder and avoid using pesticides.
- If water color is too dark, replace the water on the top with fresh water in the afternoon during high tides.
- Avoid use of chemicals to kill algae.
- Use high quality minerals, particularly a combination of calcium, magnesium and potassium, to keep the ionic balance in the pond water system.

Optimum water quality should be maintained in shrimp farming for high growth of shrimps which includes

Table 1. Water quality management

Parameters	Ideal range	Analysis	Timings
Dissolve oxygen Concentration	4 – 6 ppm	Instant kit or DO meter	5 to 6 am
Temperature	28 – 32 ° C	Thermometer	6 am and 3 pm
Salinity	10 -25 ppt	Refractometer	Anytime
Water colour	Green or brown	Visual observation	Daytime
Transparency	30 – 40 cm	Secchi Disc	12 noon
pH	7.5 - 8.3	Liquid indicator or Calibrated pH meter	6 am and 3 pm
Total alkalinity	100 –200 ppm	Use alkalinity instant test kit	Anytime
Total ammonia	< 0.5 ppm	Use ammonia instant test kit	Morning

Health and disease management

Every day check the condition of shrimp in the feed trays. If consumption of feed is poor for 3-4 days it is an indicative of health issues or occurrence of diseases in the animals. We have to do sampling at various or different locations, in the early morning to know the well being of the animals in the pond.

- We have to check for the microbial or bacterial load and water quality of shrimp pond.
- We have to observe the shrimps, there should be no variation in the body color of shrimp, and its gut should be filled with feed.
- Observing swimming behavior of shrimp to know that shrimp is healthy.
- If the tips of antenna of shrimp become black, it indicates bacterial infection.
- If the pond bottom is dirty, it will cause black colored gills.
- Check if there is any white or black spot on body of the shrimp.
- If you found any one from the above then we have to use preventive measures and treatment and have to keep the feeding area very much clean.
- Any disease outbreak is seen, have to use quality probiotics regularly and sanitation for viral outbreaks.
- Maintain proper aeration and reduce the feeding rate if DO levels reduced .
- Clean all the equipment and materials used with KMnO4 solutions.

Fig.5. White spots

Fig.6. Healthy shrimp

Effluents management:

A pond water effluent has major impact on the environment due to high nutrient content. Direct discharge of effluents into environment without treatment may affect the environment. In order to manage the effluents, we have some techniques those are:

- Efficiently use the fertilizer and feed. Control the nutrient leaching.
- Before releasing the effluents into rivers or canals it should be treated with chlorine which helps in the chemical biodegradation.
- Use of recirculation system.
- Use high – rate algal pond system.
- Drain out the pond and then discharge the effluents by physically or mechanically and keep it away from farm and let them dry and dig them into the soil.
- Use sedimentation pond for settle the effluents.

Use probiotics instead of using antibiotics

As the probiotics were used for both disease treatment and also act as a growth promoter. Antibiotics were affecting the growth of animals. An antibiotic also affects the quality of water and there by effects the environment. Probiotic is a live microorganism which beneficially affects the host. Mainly gram-positive bacteria such as Lactic acid bacteria – Lactobacillus; Bacillus; Streptococcus; Enterococcus etc. used as probiotic strain. Some probiotics also stimulate the immune system of animals. So, instead of using harmful antibiotics use probiotics.

Better harvesting practices

Harvesting should be done between 6 PM and 6 AM and should be finished within 6 – 8 hours. Shrimp not feed six hours before the harvesting. Don't exchange the water before 2 – 3 days of harvesting. But we can exchange 20% of water before one week. Usage of drag net is more efficient than cast net. Avoid using chemicals for cleaning the shrimp. For packing and for preserving the shrimp use high quality of ice. Perfect presentation obtained by placing the shrimp in transport boxes with a 2:1 ratio of crushed ice and shrimp. To prevent cross contamination use bleach and lime in harvesting area and after harvest also.

Record keeping

Record keeping is done to identify the problems in the pond environment. It is useful to learn from the past experiences. To estimate the production cost and also to find out the net profit or loss. In order to know the water quality and shrimp behavior and also growth rate record keeping is required. To maintain the feeding details, record keeping is required.

Conclusion

Aquaculture is one of the fast growing industry which provides employment to the people but now a days farmers were facing problems in the shrimp and fish culture. So, by following the Better management practices (BMPs) most of the problems were reduced and sustainable aquaculture is obtained and production cost will be reduced as well as proper growth is obtained. So that farmers can get better production and profit. BMPs like using probiotics instead of using antibiotics and effluent treatment before they were released into rivers or canals will reduce the contamination of environment. Screening of water will improve the growth of shrimp.

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T. Jagadeesh, M. Anusha, G. Ganesh and Malothu Mohan: Best management techniques in shrimp culture, AGRIALLIS, Vol -4 issue – 10 October 2022.

ISSN : 2583-0910
Agri-India TODAY
visit us at www.agriindiatoday.in
Peer reviewed
monthly newsletter

Article ID : 05/VIII/08/0825

ROLE OF ENDOSYMBIONTS IN INSECT NUTRITION

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Introduction

Symbiosis, a term derived from the Greek word *simbios*, meaning "living together," was first introduced by Anton de Bary in 1879. He described it as a lasting association between two or more distinct species, occurring at least during part of their life cycles. There are six recognized types of symbiotic relationships: parasitism (-,+), mutualism (+,+), commensalism (0,+), amensalism (-,0), synnecrosis (-,-), and neutralism (0,0). Symbiosis has played a crucial role in the evolution of eukaryotic cells. The widely accepted endosymbiotic theory proposes that organelles like mitochondria and chloroplasts originated from free-living bacteria engulfed by ancestral eukaryotic cells. Endosymbiotic organisms also contribute significantly to ecological functions such as nitrogen fixation and recycling, where bacteria or fungi convert nitrogenous waste from insect metabolism or diets into usable forms for the insects.

Types of endosymbionts

Ectosymbiont : An ectosymbiont is the one which lives outside of its host's cells.

Endosymbiont: An endosymbiont is the one which lives inside of its host's cells. Endosymbionts further divided into two types:

Primary endosymbionts : They are crucial for the host's growth, development, and survival, as they supply essential nutrients. These symbionts are housed in specialized cells called bacteriocytes or mycetocytes and are obligate in nature, meaning they cannot live outside the host. Example: *Carsonella ruddi*, *Nardonella spp. and Sitophilus symbionts.*

Secondary endosymbionts: They are not essential for the host's growth or development, but their presence can enhance the host's overall fitness. Unlike primary symbionts, they are not contained within specialized structures and are facultative, meaning they can live independently of the host. Example: *Serratia symbiotica*, *Rickettsia spp.* and *Spiroplasma spp.*

Importance of endosymbionts

Symbionts can been used for developing management strategies against insect pest populations as alternative to harmful chemical pesticides which leads lead to

- Environmental pollution.
- Risks to human health and hazards.
- Resistance, resurgence, secondary outbreaks.
- Death of beneficial insects (natural enemies), as well as, rapid loss of biodiversity.

In recent years, symbiosis has received less focus compared to interactions like predation or competition. However, it is now increasingly acknowledged as a significant evolutionary force, shaping the development and adaptation of species over time.

Exploring and harnessing the various roles of endosymbionts in their host species offers new opportunities for effectively managing major agricultural and horticultural pests, as well as controlling vector-borne diseases.

Endosymbionts influence on insect nutrition and metabolism

Many insects that rely on nutrient-poor diets like plant sap have formed symbiotic relationships with microorganisms that supply essential amino acids and vitamins they cannot produce themselves. A well-known example is the association between *Buchnera aphidicola* and aphids. Another ancient example is the symbiosis between *Sulcia* species and sap-feeding insects of the group Auchenorrhyncha, making it one of the oldest known insect symbioses. Obligate symbionts typically retain complete nutrient biosynthetic pathways, even with their significantly reduced genomes. However, some have lost genes needed to produce certain essential amino acids. For instance, *Sulcia muelleri*, the obligate symbiont of sharpshooters, can synthesize eight of the ten essential amino acids, while the remaining two are supplied by co-symbionts *Baumannia cicadellinicola* and *Hodgkinia cicadicola*. Metabolic interdependence arises when obligate symbionts lack complete biosynthetic pathways. For example, *Portiera aleyrodidarum*, the primary symbiont of the whitefly *Bemisia tabaci*, has lost three genes needed for lysine synthesis. It relies on the facultative symbiont *Hamiltonella defensa*, which retains these genes, to supply the missing lysine.

Nutrient Recycling

Symbiotic microbes are vital for nitrogen recycling in insects like shield bugs and termites by processing stored uric acid. In *Reticulitermes flavipes*, hindgut bacteria ferment uric acid from fat bodies into ammonia, CO_2, and acetate. Similarly, cockroaches, which are related to termites, host *Blattabacterium* species near uric acid deposits to aid in nitrogen recycling.

Influence on insect-plant interaction

Several recent studies suggested that food plant use of herbivorous insects can be directly enhanced by facultative endosymbionts.

E.g. The injection of a secondary symbiont *Regiella insecticola* collected from clover-adapted pea aphid to vetch aphid *Megoura crassicauda* allowed the latter that normally could not feed on clover to use as its host plant.

Endosymbionts in pest management

Due to climate change and population growth increasing challenges, insect symbionts present promising new strategies for pest management. Key approaches include using heterologous microbes, paratransgenesis, insect incompatibility techniques (IIT), and targeting essential symbionts of pests. These methods are being developed mainly to combat diseases spread by insect vectors. This discussion highlights important examples and advances in applying these strategies within the broader goal of creating sustainable, effective, and eco-friendly pest control solutions.

Conclusions

Endosymbionts significantly influence insect nutrition, fitness, and interactions with plant hosts, helping insects overcome plant defenses and even manipulate plant traits to their advantage. These microbial partners offer promising opportunities for improving pest management by targeting pests more effectively and reducing disease transmission. As microbial evolution can quickly adapt pests to plant defenses, symbiont-based strategies are increasingly important amid challenges like population growth and climate change. While current methods like the sterile insect technique are in use, further research is needed to harness symbionts fully, potentially leading to sustainable, low-tech pest control solutions that benefit agriculture, public health, and environmental conservation.

Article ID : 05/VIII/09/0825

URBAN FARMING

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Abstract
An increase in population and urbanisation are emerging as key challenges for food security in urban areas. Around 15% of the world's food is grown in urban areas. According to the Food and Agriculture Organization, urban farms supply food to about 700 million residents of cities. It is estimated that by 2050, about a quarter of the world's population will likely live in cities, contributing to rapid urban growth. The purpose of urban farming is to grow organic produce, encourage people to grow their own food and contribute to food security, proper utilisation of urban land, protect the ecosystem and maintain human health. Hence, urban farming is essential to create an abundance of food for people in need by facilitating and motivating the urban people to grow organic fruits and vegetables on terrace, balcony, rooftop and empty space. This article addresses the opportunities, challenges, various components, and types of urban farming.

Key words: Food security, Rooftop, Urban farming, Vegetables

Introduction
Urban farming is a promising solution to address food security in urban areas. An increase in population and urbanisation are emerging as key challenges for food security in cities (Abass *et al.,* 2018; Zoomers *et al.,* 2017). Around 15% of the world's food is now grown in urban areas. According to the FAO (Food and Agriculture Organization), urban farms supply food to about 700 million residents of cities. It is estimated that by 2050, about a quarter of the world's population will likely live in cities, contributing to rapid urban growth (Gu *et al.,* 2021). Hence, it is required to establish urban farms and gardens to grow organic produce, encourage people to grow their own food and contribute to food security and proper utilisation of urban land (Teoh *et al.,* 2024). In addition to this, urban agriculture also protects the ecosystem. Urban farming is essential to create an abundance of food for people in need by facilitating and motivating the urban people to grow organic fruits and vegetables on the terrace, balcony, rooftop and empty space (Bon *et al.,* 2010). Container gardening is ideal for those with little or no garden space. Further, urban farming can improve livelihood options, and create employment opportunities along with contributing to sustainable developmental goals (Somanje *et al.,* 2020). The benefits of urban farming over traditional agriculture are reduced water and pesticide usage, increasing production of local food thus minimising long distance transportation, and encouraging sustainable living in highly populated urban areas (Kafle *et al.,* 2023; Ali *et al.,* 2022).

In recent times, urban farming has increased significantly due to an increased awareness of health benefits of organically grown fresh produce (Eigenbrod and Gruda, 2015). Urban farming is also increasing by the advancement in innovation and technology of various systems involved in it (aeroponic, hydroponic, and aquaponic systems) for year round production of food (Despommier, 2020).

Components of urban farming (Maneesha *et al.,* 2019)

- Horticulture components: Vegetables, fruits, flowers, spices, medicinal and aromatic plants can be grown in urban farming.
  - Micro farming: Vertical farming, terrace farming, kitchen garden, balcony garden, etc.
  - Soilless cultivation: Aquaponics, hydroponics, aeroponics, etc.
  - Protected cultivation: Greenhouse, polyhouses, shade net, etc.
- Fish farming
- Livestock and poultry
- Mushroom cultivation

Types of urban farming

Indoor farming: In indoor farming, the plants are grown under controlled conditions. Hence, it requires specialised knowledge and initial capital investment to effectively manage and operate indoor farming facilities. The crops can be grown throughout the year regardless of the season, thereby supplies food throughout the year. Here, the crops are often grown aeroponically or hydroponically. The crops suitable for indoor faming are lettuce, cabbage and broccoli (Ampim *et al.,* 2022; Engler and Krarti, 2021; Delden *et al.,* 2021).

Rooftop farming: It involves growing of plants on the rooftop of the building utilising unused space. This type of farming is useful in urban areas where land is not available for traditional farming thereby enhancing land use efficiency and local food production in urban areas. The crops suitable for rooftop farming are lettuce, chard, etc., that can withstand direct sun exposure. This type of farming serves multiple benefits such as enhancing green space for building, local food production and consumption, and improving the air quality (Drottberger *et al.,* 2023; Rondhi *et al.,* 2018).

Vertical farming: Vertical farming is another type of urban farming that involves growing plants in vertically stacked layers in urban areas where land is limited and expensive. It enables year-round production of the crops (Avgoustaki and Xydis, 2020).

Community farming: It refers to the growing of crops in outdoor conditions to provide fresh food to the communities. The crops suitable for growing are vegetables (spinach, okra, brinjal, long beans, cucumber and pumpkins) and fruits. This farming supports local agriculture and reduces the need for long distance transportation. It not only involves in the food production but also serves as hub for social interaction, strengthens the unity in communities through outdoor physical activity, provides nutritional and therapeutic benefits, and encourages the psychological well-being of the residents, thereby having intensive impact on the residents involved in community farming. Though, it also possesses challenges such as accessibility of land, allocation of resource, and participation of community people (Giyarsih *et al.,* 2024; Tay *et al.,* 2024; Salim *et al.,* 2022).

Conclusion

Urban farming is an approach to address food insecurity and promote economic development in urban areas. It offers many benefits, such as environment sustainability, increased availability of fresh produce, serves as hub for social interaction, strengthens the unity in communities through outdoor physical activity, and provides nutritional and therapeutic benefits. Urban farming also faces challenges like pest and disease management, knowledge and skill gaps. It redirects organic waste to local farms and strengthen the local food system. It raises awareness and encourages people to grow their own food, cut down on their monthly bills, urban redevelopment, health care and creates job opportunities.

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ISSN : 2583-0910
Agri-India TODAY
visit us at www.agriindiatoday.in
Peer reviewed monthly newsletter

Article ID : 05/VIII/10/0825

DROUGHT MITIGATION FOR SUSTAINABLE AGRICULTURE PRODUCTION

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Introduction

A drought is a period of drier-than-normal conditions. Droughts can persist for days, months, or even years, often leading to significant impacts on ecosystems and agriculture in the affected regions. They also cause considerable damage to the local economy. Drought management involves specific techniques and practices aimed at optimizing the yield and quality of agricultural products in arid and semi-arid regions where irrigation water is scarce. Sustainable agriculture refers to the effective utilization of agricultural resources to meet the evolving needs of humanity, while also preserving environmental quality and conserving natural resources for future generations. Drought can be managed by use of soil moisture conservation techniques, cropping system, anti-transpirants, rain water management and alternate land use system.

Types of Drought

- **Agricultural Drought** : An agricultural drought occurs when there's a lack of sufficient moisture in the soil to support crop growth and agricultural activities. This can be caused by a deficiency in rainfall, changes in temperature, or other factors that influence water availability for plants. Agricultural droughts can lead to reduced crop yields, livestock stress, and economic losses for farmers and related industries.
- **Meteorological Drought:** It is a period of time when there is less rain than normal or a rainfall deficit, in a specific area. According to India Meteorological Department (IMD) the meteorological drought is divided in to three types.
  1. Moderate Drought: ±75% of normal RF
  2. Severe Drought: ±50% of normal RF
  3. Disastrous Drought: ±25% of normal RF
- **Hydrological Drought:** This drought results if meteorological drought is prolonged for a long period. It is associated with depletion of surface water and drying up of rivers and lakes.

Consequences of Drought :	**Effects of Drought on Plants**
▪ Shortage of water ▪ Desertification ▪ Death of livestock ▪ Lack of water for irrigation ▪ Reduced crop yield ▪ Migration of people ▪ Scarcity of seed	▪ Loss of turgidity ▪ Photosynthesis ▪ Increase in number of stomata ▪ ABA accumulation ▪ Rolling and wilting of leaves ▪ Reduced tillering ▪ Forced maturity ▪ Reduction in productivity

Sustainable Agriculture:
Sustainable agriculture is the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving the natural resources.

Principles of Sustainable Agriculture:

- **Aspects of sustainable agriculture**
    1. Achieving yield stability
    2. Reducing input use
    3. Conserving natural resources

- **Achieving sustainability**
    (a) Minimize external input use: - Fertilizer, seed, agrochemical.
    (b) Maximize benefits from natural processes: - Photosynthesis, nitrogen fixation, biomass break down.
    (c) Optimize the use of internal resource: - Water, soil, perennials and native crop varieties.

Mitigation Strategies for Drought Management:
1. Soil Moisture Conservation:

- **Improve infiltration rate**
    - Conserve every drop of rainfall.
    - Tillage practice- minimize surface runoff and enhance the soil's capacity to retain moisture
    - *In-situ* moisture conservation.
- **Selection of crops:**
    - Short duration crops.
    - Drought resistant variety
    - Cover crops.
    - Hairy and small leaves.

- **Package of practices**
  - Seed treatment.
  - Optimum spacing.
  - Judicious use of fertilizer.
- **Use of mulches**
  - Any material used (spread) at surface or vertically in soil to check evaporation, improve soil water and soil productivity is called mulch and process of applying mulches to soil is known as mulching.
  - Mulching aids in retaining soil moisture, moderating root-zone temperatures, and suppressing the growth of weeds and thus helps crops during moisture stress conditions. *e.g*. Dust mulch, Straw mulch, Plastic mulch, Vertical mulch etc.

2. Cropping System

- It represents cropping patterns used on a farm and their interaction with farm resources, other farm enterprises and available technology which determine there make up.
- Cropping system is most important for mitigating the drought. There are various cropping systems in arid and semi-arid region for escaping the drought. *e.g*. Inter cropping, Mixed cropping, Alley cropping, Relay cropping

3. Use of Anti-transpirants

- Anti-transpirants are the materials or chemicals that applied to transpiring plant surfaces for reducing water loss from the plant.
- Hardly 1 % water is utilized in metabolic activities of plant and remaining water lost through transpiration.

- **Types of ATs**
  - Stomata Closing type: They reduce water loss through closing stomata. *e.g*. Phenyl Mercuric Acetate (PMA), Atrazine
  - Film forming type: -It checks transpiration loss of water due to formation of thin film which acts as physical barrier. *e.g*. Mobileaf, Oils, Waxes, Hexadeconal, Silicone
  - Reflectant type: -These chemicals reflect the radiation and reduce leaf temperature. *e.g*. Kaolin, Calcium bicarbonate
  - Growth Retardants: These chemicals reduce shoot growth and increase root growth of all trees and thus enable the plants to resist drought. *e.g*. Cycocel (CCC), Maleic hydrazide (MH)

4. Rain Water Management

- **Water** harvesting and recycling: Collection and storage of rain water, either runoff or stream flow for securing and improving water availability for crop growth under unirrigated condition.
- Macro-water harvesting: It is a technique for collecting rainwater runoff from a large area and storing it for agriculture use.
- Micro-water harvesting: It is a technique that uses small catchments to collect and store runoff water for later use.

5. Alternate Land Use System

- It is defined as an effective economic utilization of land without harming the natural resource structure based on land capability.

- Land use systems which are alternatives to crop production.
- Same lands may be suitable for range/pasture management, for tree farming, ley farming, dryland horticulture and agro-forestry systems including alley cropping.
- All these systems which are alternative to crop production are called as alternate land use systems.
- Diversification of land according to land capability classes increase the land use efficiency.

Alternate land use system classified as-

- Agri-horticultural system = Agriculture crops + Horticulture
- Agroforestry = Agriculture crops + Forest crops
- Agri-Silvicultural system = Agriculture crops + Tree crops
- Silvi-pastoral system = Silviculture + Pasture management

Advantages of Alternate Land Use System

- Control soil erosion
- Soil improvement
- Creating congenial and conductive microclimate

Conclusion

It is evident that diverse soil moisture conservation techniques, cropping systems, anti-transpirant use and rainwater management strategies significantly enhance crop yields and water-use efficiency. Practices like ridge-furrow planting, mulching, deep tillage and compartmental bunding consistently improve soil moisture retention, leading to higher yields in various crops. Intercropping and diversified cropping systems, such as pearl millet + pigeon pea, have shown improved moisture efficiency. Additionally, anti-transpirant sprays, such as kaolin and PMA, further boost yield by conserving soil moisture. Effective rainwater management through timely irrigation also enhances yield, while alternate land-use systems, such as mango + blackgram plantations, indicate potential for preserving higher soil moisture content.

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Article ID : 05/VIII/11/0825

BIOFERTILIZER: AN OVERVIEW

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Introduction

In recent years, we have seen a doubling of the human population and a concurrent doubling of food production. Plant nutrition has played a key role in this dramatic increase in demand for and supply of food. Increases in crop production have been made possible using commercial man-made fertilizers. The use of nitrogen (N) fertilizer has increased almost ninefold and phosphorus (P) more than fourfold, the tremendous increase of N and P fertilization, in addition to the introduction of highly productive and intensive agricultural systems, has allowed these developments to occur at relatively low budgets. The increasing use of fertilizers and highly productive systems have also created environmental problems such as deterioration of soil quality, surface water, and groundwater, as well as air pollution, reduced biodiversity, and suppressed ecosystem function. These substances have a negative impact on soil fertility, increased salinity, soil holding capacity, and nutrient inconsistency in the soil (Savci, 2012). Biofertilizers are a material that comprehends living microorganisms that, when applied to seeds, plant surfaces, or soil, promote growth by increasing the supply or availability of primary nutrients to the host plant. Applying biofertilizers as soil or seed inoculants causes them to proliferate, aid in the cycling of nutrients, and increase crop productivity (Singh *et al*., 2011). By fixing atmospheric nitrogen, solubilizing insoluble phosphates, and producing compounds in the soil that promote plant growth, biofertilizers increase soil fertility. These are mixtures that include active or dormant cells of effective strains of microorganisms that, when given as seed or soil, facilitate the uptake of nutrients by agricultural plants through interactions with them in the rhizosphere. They quicken several microbial activities in the soil that increase the amount of nutrients available in a form that plants can readily absorb.

Types of Biofertilizers

Sr. No.	Types of biofertilizers	Examples
N_2 fixing Biofertilizers		
1.	Free-living	*Azotobacter*, *Beijerinkia, Clostridium*, *Klebsiella*, *Anabaena*, *Nostoc*
2.	Symbiotic	*Rhizobium*, *Frankia*, *Anabaena*
3.	Associative Symbiotic	*Azospirillum*
P Solubilizing Biofertilizers		
1.	Bacteria	*Bacillus megaterium* var. *phosphaticum*, *Bacillus subtilis*, *Bacillus circulans*, *Pseudomonas striata*
2.	Fungi	*Penicillium* sp., *Aspergillus awamori*
P Mobilizing Biofertilizers		
1.	Arbuscularmycorrhiza	*Glomus* sp., *Gigaspora* sp., *Acaulospora* sp.,

Sr. No.	Types of biofertilizers	Examples
		Scutellospora sp. & *Sclerocystis* sp.
2.	Ectomycorrhiza	Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.
3.	Ericoid mycorrhizae	*Pezizellaericae*
4.	Orchid mycorrhiza	*Rhizoctonia solani*
Biofertilizers for Micronutrients		
1.	Silicate and Zinc solubilizer	*Bacillus* sp.
Plant Growth Promoting Rhizobacteria		
1.	*Pseudomonas*	*Pseudomonas fluorescens*

Nitrogen fixing biofertilizer (NBF)

Nitrogen (N) is one of the most essential nutrients for growth and productivity in plants. Although it is present in the atmosphere at 78 percent, it remains unavailable for plant use. Nitrogen must be converted to ammonia in order to use the atmospheric Nitrogen, which can be readily assimilated by plants via the biological Nitrogen fixation process (BNF). Nitrogenase is an enzyme complex that nitrogen-fixing microorganisms employ to transform atmospheric nitrogen into ammonia (Hoffman *et al*., 2009).

Phosphorus solubiliser

The second key mineral nutrient required in substantial quantities by plants is Phosphorus (P). There is a large amount of P present in the soil, but it is normally fixed (i.e. P-fixation) at the point of application and thus, becomes insoluble and unavailable to plants. The phosphorus that is insoluble is present as inorganic substances such as apatite or as one of many organic forms including inositol phosphate (soil phytate), phosphormono-esters, and phosphotriesters. The application of Phosphorus solubilizing biofertilizer (PSB) is used to help remedy and make P more bioavailable and bioaccessible to promote growth and development of plants. For example, PSB includes phospho-bacterin, which helps to solubilize insoluble phosphates (e.g. di-and tri-calcium phosphates, hydroxyapatites, and rock phosphates) and makes them more accessible to plants.

Potassium solubilisers

Potassium is one of the key macronutrients that the plant requires to improve its biological processes besides N and P. The availability of total K in the soil is high, but only limited quantities are available for use by plants. There exists three forms of Potassium at the same time in the soil system; namely, unavailable, slowly available, and readily available forms. The application of biofertilizers can help remediate this situation by solubilizing the unavailable K and thereby furnishing it in available forms for plant uptake.

Silicate-solubilizing bacteria (SSB)

One of the main components of soil is silicon (Si). It is mostly taken up by the roots of plants from soil water as monosilicic acid $Si(OH)_4$. Si is crucial in mitigating a range of abiotic stressors, including radiation, UV light, high temperatures, cold, and drought, as well as abiotic stressors such as metal toxicity, salt tolerance, and nutritional imbalance. It imparts drought resistance by maintaining the rate of photosynthesis, leaf erection, water balance and xylem vessels structure during higher transpiration rates which mainly results from high temperature and moisture deficiency.

Iron sequestration

Iron (Fe), an essential micronutrient, plays vital role in chlorophyll formation, photosynthesis, respiration and various enzymatic reactions. Iron is absorbed by plants either Fe2+ (ferrous cation) or Fe3+ (ferric cation) forms. All living beings need Fe. Under anaerobic conditions, it forms insoluble hydroxides and oxyhydroxides and predominantly occurs as Fe3+ (Mahdi *et al*., 2010).

Advantages of biofertilizer :

- Biofertilizers act as supplements to chemical fertilizers.
- Biofertilizers are cost-friendly and can aid to decrease consumption of such fertilizers.
- Microbes in biofertilizers provide atmospheric nitrogen directly to plants.
- They aid in solubilisation and mineralisation of other plant nutrients like phosphates.
- Better synthesis and availability of hormones, vitamins, auxins and other growth-promoting substances improves plant growth.
- On an average crop yield elevates by 10-20 percent by their use.
- They help in the multiplication and survival of beneficial micro-organisms in the root region (rhizospheric bacteria).
- They control and inhibit pathogenic soil bacteria.

Amount of Nutrients Fixed by Some Biofertilizers in Various Crops

Microorganisms used as biofertilizer	Nutrient fixed (kg/ha/year)	Beneficiary crops
Rhizobium	50 to 300 kg N/ha	Groundnut, Soyabean, Redgram, Green gram, Black gram, Lentil, Cowpea, Bengal Gram, Fodder legumes
Azotobacter	0.026 to 20 kg N/ha	Cotton, Vegetables, Mulberry, Plantation crop, Rice, Wheat, Barley, Ragi, Jowar, Mustard, Safflower, Tobacco, Fruits, Spices, Ornamental flowers
Azospirillum	10-20 Kg N/ha	Sugarcane, Vegetables, Maize, Peral millet, Rice, Wheat, Oil seeds, Fruit and Flowers
Blue green algae	25 Kg N/ha	Rice, Banana
Azolla	900 Kg N/ha	Rice
Phosphate solubilizing bacteria and fungi	Solubilize about 50-60 % of fixed phosphorus in soil	All crops

Conclusion

In order to feed the rising population with the deficit of available nutrients, the planet definitely needs agricultural production to flourish and that too indeed in a sustainable and environmentally friendly way. It is therefore undoubtedly important to reevaluate many of the current agricultural methods including the use of various agrochemicals. These agrochemicals are hazardous to the eco-system as well as threats to the soil, bio-diversity and living organism. Biofertilizer, the microbial inoculant is an eco-friendly alternative to chemical fertilizer, protects lithosphere, improves biosphere by protecting air, water, soil pollution, and eutrophication and enhances yields of agriculture produce. It helps to enrich the soil with macro- and micro-nutrient and also by releasing plant growth regulators. Biofertilizers are classified as N-fixing, phosphate solubilizing, phosphate mobilizing, potassium solubilizing, potassium mobilizing, and sulfur oxidizing.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/12/0825

SPINE LESS CACTUS *(Opuntia ficus indica*) BOON TO FARMERS OF ARID REGIONS

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Abstract
Biomass production is a challenging task in arid and semi-arid regions due to climatic constrains faced. Cactus pear is gaining importance in recent times due its adoptability to harsh climatic conditions and produce good amount of biomass. Cactus pear cultivation provides livelihood to the farmers of arid regions by its multiple uses from cladodes and fruits. As cattle rearing is backbone of farming community in arid regions obtaining fodder year-round is major problems as dry seasons facing huge fodder crisis, cactus pear is best alternate source of fodder along with it also gives several other commercial benefits with proper maintenance. Cladodes also used for leather production, composting and salad. Fruits are used for preparing juice and several other products in food industry. Hence cactus pear cultivation can be best source to support the farming community in arid regions.

Key words: Arid regions**,** cactus pear, cladodes, fodder, compost.

Introduction
Climatic conditions of arid and semi-arid regions are characterized by high temperatures, low and erratic rainfall, high evapotranspiration, high wind speed and low soil fertility, salinity all together leads to low agricultural crop productivity and also make the people livelihood a challenging task under such harsh conditions. Under such circumstances several crop varieties and adaptation technologies have been developed to obtain better productivity under such harsh conditions. But providing economical benefits is always remaining as hurdle in agricultural systems. Cactus pear (*Opuntia ficus-indica)* is one of miracle plant which is having xerophytic nature and able produce higher biomass under harsh arid climatic conditions. It also having multiple uses with its cladodes and fruits. It serves as food, fodder and other commercial products production.

Uses of cactus pear
Use as fodder
Cattle rearing is the major livelihood for the people living in arid and semi-arid regions. Water scarcity is the common problem faced by the people hence making supplementation of year-round fodder to cattle a challenging task. Cactus pear which is drought tolerant plant can survive and produce biomass year-round which is good source of fodder to cattle. Cladodes of cactus pear contain about 85% water, crude protein of 4-12%, crude fibre 12-19%, total ash 15-24% and calcium 3.7%. high water content help in reducing daily water need of cattle. It has high soluble carbs but low in protein and fibre hence, there is a need to mix other protein and fibre source such as legumes stover, paddy and wheat straw for feeding cattle. Cladodes are harvested and made into small pieces and mixed with other additives in 1:3 ratio then feed to cattle. Studies at CAZRI showed cactus pear plantation at spacing of 3 m x 2 m produced 30 tonnes/ha biomass.

Fig. 1 Several uses of cactus pear

Use as vegetable/food

Cladodes which are also known as nopales at early stage are harvested and consumed as salad and also vegetable, pickles. The young nopales are tender and light yellow in colour are best as vegetables. Several other food products are prepared from the nopales. Fruits of cactus pear are used for preparing juices and squash. Fruits are rich source of antioxidants and vitamins. Fruit leather is prepared from the fruit pulp of cactus fruits known as pestil consumed in Arab countries.

Cactus for leather production

Cactus leather which is also known as vegan leather is prepared from the mature cactus pear cladodes. It serves as alternate source for animal leather which is ecofriendly and sustainable practices. Cactus leather is used for preparation of several leather products such as footwear, bags, clothes, belts, furniture and automotive interiors.

Cactus as compost and biogas production

Cladodes of cactus can be used as compost after partial decomposition. Clades are cut into pieces and mixed with other organic materials and left for few days to become a good compost. It serves as alternate source of nutrients and helps in enhancing soil fertility and microbial activity. Cladodes can also used for biogas production. Cladodes after cutting added to anaerobic digestion units to produce methane gas. About 0.36 m^3 kg/DM biogas is produced with 60-70% methane. The biogas slurry from digestion chamber can be used as organic manure in crop production.

Colour from fruit and cochineal

The fruits of cactus pear are having bright coloration such as red, purple, yellow and orange due to presence of various antioxidants. Hence these fruits are widely used in food industry as colouring agents. Cochineal dye is prepared from the cochineal insects which live on the cladodes of cactus pear. Rearing of this insect is done on cladodes and from this insect's dye is extracted.

Conclusion

Cactus pear the miracle crop of 21st century serves as solution to various problems of farmers in arid regions. It multiple uses make it emerging new hope for dairy industry of arid regions. Its major use as fodder along with other mixtures shown best results. Other uses including usage in food industry, leather production, dye preparation and compost preparation having a very good scope to build up economic benefits to the farmers. Hence, research on growth and management should further focused to get better results and new methodologies in cactus pear cultivation.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/13/0825

CITES: SAFEGUARDING BIODIVERSITY THROUGH INTERNATIONAL TRADE REGULATION

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Introduction

The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) is a landmark multilateral environmental agreement established to regulate international trade in wild animals and plants, ensuring that such activities do not jeopardize their survival in the wild. Prompted by escalating concerns over unregulated wildlife trade and its impact on global biodiversity, CITES was adopted in 1973 and came into force on 1 July 1975. There are 184 member countries referred as "parties", CITES stands as one of the most comprehensive and widely implemented conservation framework worldwide. The convention provides a robust international legal structure for the sustainable, legal and traceable trade of over 38,000 species of wild fauna and flora (Raymakers, 2006). While CITES is legally binding, it does not supersede national laws instead it requires each party to implement its provisions through domestic legislation. The CITES Secretarial administered by the United Nations Environment Programme (UNEP) and headquartered in Geneva Switzerland coordinates global efforts to ensure that international trade supports, rather then undermines the survival of species in the wild.

Objectives and need of CITES

Why CITES was established

In the 1960s and early 1970s, unregulated international trade posed severe threats to many species, some of which faced imminent extinction. Recognizing the transboundary nature of wildlife trade, there was an urgent need for an international regulatory mechanism. CITES emerged to address this challenge by coordinating global efforts toward sustainable trade and preventing the overexploitation of wild fauna and flora.

Core objectives

a) To prevent the overexploitation of wildlife due to international trade.
b) To promote sustainable and legal trade of wildlife resources.
c) To combat illegal trafficking of endangered species.
d) To provide a transparent permit system ensuring traceability of traded species.

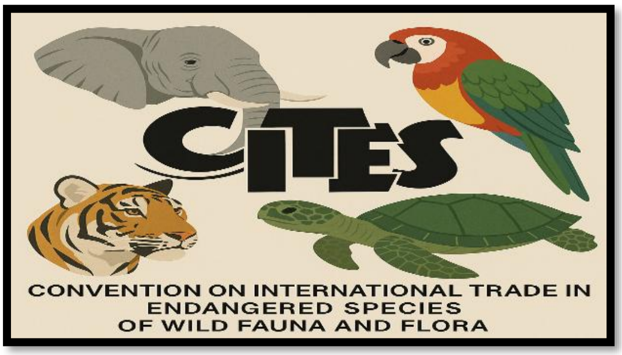

Figure: Official logo of CITES **Figure: CITES logo representing endangered species**

Structure and functioning of CITES

Appendices and level of protection

CITES classifies species into three appendices based on the degree of protection they require:

Appendix	Protection level	Examples	Trade regulation
I	Highest (Threatened with extinction)	Gorillas, Tigers, Giant pandas	Trade only in exceptional cases (e.g. for research purpose), commercial trade banned
II	Moderate (May become threatened without regulation)	American alligator mahogany, Corals	Regulated trade, requires export permit and non-detriment findings
III	Basic (Protected in at least one country)	Map turtles, Walruses	Requires co-operation from other countries, export permits and certificates of origin necessary

Permit and licensing system

CITES mandates a stringent licensing system to authorize all imports, exports, re-exports and introductions from the sea. Each party must designate:

a) **Management authorities** which oversee the implementation of permits and compliance.
b) **Scientific authorities** which evaluate the impact of trade on species survival and advise on non-detriment findings.

Implementation and governance

Legal binding and national legislation

Although CITES is legally binding, it does not replace national laws (Smith *et al.*, 2011). Each member country is required to enact domestic legislation in alignment with CITES provisions. The ensures that the conventions rules are enforceable within national jurisdictions.

Conference of the Parties (CoP)

The Conference of the Parties (CoP) is the principal decision making body of CITES. Convening every 2-3 years, the CoP reviews implementation, addresses conservation challenges and considers proposals for amendment to species listing in the appendices (Wilson, 2023).

India and CITES

India became a party to CITES on July 20, 1976 and the convention entered into force for the country on October 18, 1976. India hosted the 3rd CoP in New Delhi in 1981, showcasing its commitment to global wildlife conservation. Domestically, CITES is implemented through the Wildlife (Protection) Act,1972 and enforced by the Wildlife Crime Control Bureau (WCCB). India is a mega biodiversity country plays a significant role in CITES deliberations and enforcement, actively curbing illegal trade and participating in species conservation programs.

Achievements and impact

CITES has led to the regulation and in many cases recovery of several species by curbing unsustainable trade. Success stories include:

a) Recovery of African elephants through ivory trade restrictions.
b) Protection of vicunas and tropical hardwoods like rosewood and ebony.
c) Regulation of coral and orchid trades.

CITES has also facilitated international collaboration among customs, police and wildlife enforcement agencies, aiding the global fight against wildlife crime.

Challenges

Despite its noteworthy successes, CITES faces significant challenges in its mission to safeguard biodiversity through regulating international trade. One major obstacle is the presence of enforcement gaps. In many countries, limited institutional capacity and a lack of resources hinder the effective implementation of CITES regulations. This situation is further complicated by the persistence of illegal wildlife trade, which remains a highly lucrative and well-organized global enterprise, often fueled by networks of corruption. Additionally, CITES current regulatory framework a limited scope, focusing primarily on mitigating trade-related threats. As a result, it does not comprehensively address other critical drivers of biodiversity loss such as habitat destruction, climate change and environmental pollution.

Future directions

To maintain its relevance and continue effectively protecting endangered species, CITES must evolve in response to emerging threats and technological advancements. Strengthening the implementation of CITES provisions is essential, this involves improving training, capacity building and transparency among member parties. Given the rise of online commerce, there is a growing need to develop regulatory framework that can monitor and control wildlife trade conducted through digital platforms. Furthermore, with climate change posing new risks to ecosystems and species survival, integrating climate resilience into CITES species conservation assessments has become a critical future direction. Addressing these priorities will help ensure that CITES remains a cornerstone of global biodiversity protection in the decades to come.

Conclusion

CITES stands as a pivotal international agreement in the realm of wildlife conservation, balancing the regulation of global trade with the imperative of species survival. Over the decades its framework has not only inspired the development and enhancement of other key environmental treaties but it has also proven adaptable evolving in response to emerging conservation challenges worldwide. As the urgency of biodiversity loss grows and threats to wild flora and fauna intensify, the relevance of CITES increases. Its central role in promoting international cooperation, advocating for sustainable use and ensuring legal trade continues to provide essential protections for species under pressure from human activity.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/14/0825

FIELD-BASED DECISION MAKING IN COCONUT IPM: ROLE OF AESA

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Introduction

The coconut palm, often revered as *'Kalpavriksha'* or the "tree of heaven," is valued for its versatility, with every part of the plant offering economic or utilitarian significance. In India approximately 10 million people rely on coconut cultivation and related activities for their livelihood, either directly or indirectly. Globally, India holds the distinction of being the largest producer of coconuts, while ranking third in terms of area under cultivation. According to the 2023–24 estimates (Coconut Development Board), the country's annual coconut production stood at 21.37 billion nuts, cultivated over an area of 2.165 million hectares, with an average productivity of 9,871 nuts per hectare. The states of Kerala, Tamil Nadu, Karnataka, and Andhra Pradesh dominate national production, collectively accounting for over 90% of both area and output.

In India, coconut cultivation is significantly affected by major pests such as the rhinoceros beetle (*Oryctes rhinoceros*), red palm weevil (*Rhynchophorus ferrugineus*), black-headed caterpillar (*Opisina arenosella*), white grub (*Leucopholis coneophora*), and the eriophyid mite (*Aceria guerreronis*), which are prevalent across all coconut-growing regions. In addition, rodent infestations pose a serious threat in island ecosystems and water-locked areas. Other minor pests include coreid bugs, slug caterpillars, which affect their health and productivity.

In many cases, farmers rely heavily on chemical sprays to control these pests. While these might offer quick relief, over time, they can harm the soil, environment, and even reduce profits due to increased input costs and resistance buildup. To overcome these problems, AESA (Agro-ecosystem analysis) based Integrated Pest Management (IPM) is the best solution. The **Agro-Ecosystem Analysis (AESA)** is a decision-making tool under IPM, which empowers farmers to observe field ecology, identify pests, natural enemies and make informed interventions based on Economic Threshold Levels (ETL). AESA emphasizes minimizing pesticide use and conserving biodiversity.

General AESA Practices:

AESA-Based IPM Practices in Coconut:

- Conduct regular field visits and AESA monitoring every 7–10 days.
- Observe the number of pests and beneficial insects in each palm.
- Record natural enemy populations and pest damage symptoms.
- Avoid pesticide application if natural enemy–pest ratios are favorable (i.e., natural enemies can suppress the pest below economic damage levels).
- Take up control measures only if ETL is crossed:
- ➢ **Rhinoceros beetle**: >10% palms infested.
- ➢ **Red palm weevil**: >1% palms infested.

- **Black headed caterpillar**: infestation of outer 2–3 leaves with dead galleries.
- **Eriophyid mite**: >30% nuts showing severe damage.
- **White grubs**: 5% seedlings or 10% mature palms showing yellowing/wilt.

a) Rhinoceros beetle (*Oryctes rhinoceros*)

The rhinoceros beetle is a widely distributed and destructive pest in coconut plantations, particularly damaging to both juvenile and mature palms. Adults bore into unopened spindle leaves, fronds, spathes and occasionally tender nuts, creating characteristic V-shaped or diamond-shaped cuts and holes. These feeding injuries not only reduce the palm's photosynthetic efficiency and vigour, but also lead to inflorescence damage, resulting in nut loss. In young palms, beetles may enter through the collar region, causing symptoms like twisted spindles, dead heart and deformed leaflets, leading to stunted growth, delayed flowering or even death. Petiole damage may cause frond breakage, further weakening the tree.

The beetle breeds in decaying organic matter such as dead coconut logs, stumps, cattle dung, compost and farmyard manure. Its life cycle lasts around six months, with peak infestations typically observed from June to September, although initial breeding activity is common between February and April.

Infestation by this pest is particularly serious as it creates entry points for other lethal pests like the red palm weevil and fungal pathogens such as bud rot and leaf rot. On average, rhinoceros beetle damage accounts for a 10% reduction in nut yield, making it a pest of major economic importance in coconut cultivation.

b) Eriophyid mite (*Aceria guerreronis*)

The eriophyid mite, *Aceria guerreronis*, is one of the most damaging pests of coconut, first reported in India in 1998 from Kerala. Since its introduction, it has rapidly spread across all major coconut-growing regions along both the West and East coasts.

The mite infests young coconut nuts (buttons) shortly after pollination, colonizing the soft tissues beneath the perianth. Early symptoms appear about a month after infestation as white or yellow triangular patches, which later turn brown, developing into warts and longitudinal splits on the nut surface. Severe infestation leads to premature nut shedding, malformed nuts and difficulties in de-husking due to poor husk quality. Damage is highest during the summer months (March to May) when mite populations peak due to wind-assisted dispersal. In the initial years of infestation, yield losses reached up to 70%, with an average reduction of 30.94% in copra and 41.74% in husk production. Fibre quality was also significantly impacted, with a 26–53% reduction in fibre length from affected nuts.

However, recent surveys indicate a notable decline in infestation levels, with current losses ranging between 8–12%, reflecting the effectiveness of improved pest monitoring and management practices.

c) Red palm weevil (*Rhynchophorus ferrugineus*)

The red palm weevil is one of the most destructive and fatal pests of coconut, particularly affecting young palms aged 5–20 years, with dwarf varieties being highly susceptible. The pest is often associated with pre-existing damage, such as wounds caused by rhinoceros beetle, bud rot, or leaf rot, which serve as entry points for egg-laying. Once hatched, the grubs bore into the crown, trunk or collar region, feeding internally near the growing point, making early detection difficult. Typical symptoms include wilting of the central spindle, yellowing of inner fronds, splitting of leaf bases, presence of holes with oozing brown fluid, extrusion of frass, and an audible gnawing sound from feeding grubs.

In severe cases, the pest causes drying of heart leaves and crown toppling in advanced stages. The pest completes its life cycle entirely within the palm, with larvae passing through 10 instars over 36–78 days, followed by a pupal stage of 22–25 days and an adult lifespan of 60–70 days. Infestation can lead to 5–10% palm mortality annually in some regions, making it a pest of serious economic concern.

d) Black headed caterpillar (*Opisina arenosella*)

The leaf-eating caterpillar is a serious defoliator of coconut, commonly infesting coastal, backwater, and waterlogged tracts, and in recent years, spreading to interior regions of peninsular India. The pest becomes especially severe during the summer months (February to May), with natural decline observed during the southwest monsoon.

The larvae construct silken galleries reinforced with excreta and leaf fragments on the underside of coconut leaflets, where they feed on the chlorophyll-rich parenchyma tissue. This damage leads to drying of the outer and middle leaf whorls, reducing the palm's photosynthetic capacity, resulting in significant yield decline. In severe cases, older leaves appear scorched and only the inner green fronds remain, giving the plantation a burnt appearance from a distance.

The infestation not only reduces coconut yield up to 40% loss in endemic areas, but also renders the leaves unfit for traditional uses like thatching or basket making. Live or dead caterpillars and their silken galleries on the leaf undersides serve as key diagnostic signs of the pest.

e) White grub (*Leucopholis coneophora*)

White grubs are significant root-feeding pests of coconut, particularly prevalent in sandy loam soils of Kerala and Karnataka. These grubs are the larval stage of chestnut-brown beetles, which emerge from the soil during pre-monsoon showers in May–June, typically around sunset. After laying eggs in the soil, grubs emerge within three weeks and begin feeding first on organic matter and roots of intercrops like cassava, sweet potato, Colocasia, and banana, later shifting to coconut roots.

In nursery seedlings, the grubs damage tender roots and bore into the collar region, leading to spindle drying, yellowing of outer leaves, and eventual seedling death. In mature palms, continued infestation results in yellowing of leaves, premature nut fall, delayed flowering, tapering of the crown, poor growth and a notable reduction in yield. The peak grub population in coconut basins is observed during September–October, and the pest completes its life cycle in one year.

Minor Pests

f) Coreid bug (*Paradasynus rostratus* Dist.)

The coreid bug is an emerging pest of coconut, commonly found in coastal and high-range areas of Kerala, with higher incidence reported in Trivandrum, Wayanad, and Kasaragod districts. It also feeds on other host plants like cashew, guava, tamarind, cocoa, and neem.

Both nymphs and adults feed on tender coconut buttons (1–3 months old) and young nuts, puncturing the meristematic tissue and injecting toxins, which lead to necrosis, button shedding and malformation of retained nuts. Affected nuts often show furrows, crinkling, gummosis, and sometimes develop into barren nuts. Female flowers may also be attacked before pollination, resulting in failed fruit set.

The pest is active from June to February, with peak population during October to December, particularly in the post-monsoon period. Infestation levels tend to rise in response to ecological changes and environmental disturbances, making regular monitoring and timely management essential.

g) Slug caterpillars (*Contheyla rotunda, Parasa lepida*, *Darna nararia*)

Early-instar caterpillars feed on the underside of coconut leaflets, scraping surface tissues and creating glistening patches. These areas soon develop into black halo-like spots, which may merge into larger lesions. Initially, only the lower epidermis is consumed, leaving the upper (adaxial) surface intact. As the larvae mature, they feed aggressively on leaf tissues, often leaving behind only the midribs.

This damage is frequently worsened by secondary infection from grey leaf blight fungus (*Pestalotiopsis palmarum*), which enters through larval feeding wounds. Severely infested palms exhibit a scorched or burnt appearance, with most functional leaves dried up, affecting photosynthesis and leading to premature nut shedding and reduced yield.

h) Rodents (*Rattus rattus wroughtoni*)

Rats are destructive mammalian pests in coconut plantations, particularly targeting tender nuts aged 3 to 6 months. They gnaw a distinct 5 cm hole near the stalk region, leaving damaged nuts hanging on the bunch for 2 to 6 days before shedding. These damaged nuts, often found beneath affected palms, are a key indicator of infestation.

In addition to tender nuts, rats also damage leaf stalks, unopened spathes, female flowers and even mature nuts, both in the field and during storage. In severe cases, they may even construct nests in the crown using coconut leaflets and plant debris, further harming the tree's productivity and structure.

Natural Enemy Conservation

- Conserve predatory mites (*Neoseiulus baraki*), parasitoids (*Goniozus nephantidis*, *Elasmus nephantidis*, *Brachymeria nosatoi*, *Chrysochalcissa oviceps*, *Gryon homeoceri*), entomopathogens (*Hirsutella thompsonii*, *Metarhizium anisopliae*, *Beauveria bassiana*) and predators like weaver ants (*Oecophylla smaragdina*) by avoiding indiscriminate pesticide sprays.
- Use botanical and biorational products wherever possible.

Conclusion

An integrated approach combining cultural, mechanical, biological and chemical methods has proven effective in managing major coconut pests such as the rhinoceros beetle, red palm weevil, eriophyid mite, leaf-eating caterpillar, white grubs, coreid bug and rodents. Practices like field sanitation, crown cleaning, light trapping and balanced nutrition play a critical role in prevention, while manual removal, pheromone traps and mechanical barriers help reduce pest populations.

The use of biocontrol agents, including parasitoids, entomopathogenic fungi, viruses and nematodes, forms the core of eco-friendly pest suppression. Botanical formulations like neem-based products and targeted chemical applications serve as supportive measures when pest thresholds exceed economic levels.

Successful implementation of these strategies requires regular monitoring, timely interventions and where possible, a community or group approach to cover large, contiguous coconut-growing areas. The integration of these practices ensures sustainable pest management, improved yield and long-term crop health in coconut ecosystems.

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Pest	Cultural Control	Mechanical Control	Biological Control	Chemical & Botanical Control
a) **Rhinoceros Beetle** (*Oryctes rhinoceros*)	• Removing decaying logs, compost heaps, and dead palms • Annual crown cleaning • Monitoring the spindle and collar regularly • Use of *Clerodendron infortunatum* biomass in compost (10%)	• Manually remove beetles from the crown with GI hooks and treat the wounds with fungicide paste	• Release of virus-infected beetles (OrNV) @ 10–12/ha • Applying Metarhizium anisopliae @ 5 × 10^{11} spores/m³	• Filling the three leaf axils with neem/ marotti/ pongamia cake (250 g) combined with sand (250 g) three times annually. • Placement of 12 g naphthalene balls in spindle axils every 45 days. • Utilization of perforated sachets containing chlorantraniliprole (5 g), fipronil (3 g), or botanical cakes (2 g each). • Installation of pheromone traps (*Oryctolagus*) at a density of 1 per hectare.
b) **Eriophyid Mite** (*Aceria guerreronis*)	• Removal and burning of infested nuts/spathes • Application of neem cake (5 kg) + compost/cow dung (50 kg) per palm	• Removal of mite-infested plant parts (nuts, spathes) during crown cleaning	• Application of *Hirsutella thompsonii* (20 g/L) talc formulation (1.6 × 10^8 cfu) three times/year • Conservation of predatory mites, especially the phytoseiid mite,	• Root feeding azadirachtin 10,000 ppm @ 10 ml + 10 ml water • Spraying with neem oil–garlic–soap emulsion (200 ml neem oil + 200 g garlic + 50 g soap/10 L water) • Spraying azadirachtin

Pest	Cultural Control	Mechanical Control	Biological Control	Chemical & Botanical Control
			Neosieulus baraki, which is predominantly found along with the mite colonies in all pest-infested areas.	1% @ 4 ml/L (Apr–May, Oct–Nov, Jan–Feb) • Three Sprayings of palm oil (200 ml) + sulphur (5 g) on bunches.
c) **Red palm weevil** (*Rhynchophorus ferrugineus*)	• Avoiding injuries to the palm trunk and crown (e.g., during leaf cutting or climbing) • Treating mechanical wounds with coal tar to prevent egg laying • During frond cutting, retain 120 cm petiole to block pest entry • Adoption of intercropping to reduce pest attraction and improve biodiversity	• Removal and burning of palms at advanced infestation stages to destroy all life stages inside the trunk • Use prophylactic leaf axil filling to prevent predisposing damage	• Installing pheromone traps (Ferrolure) in plastic buckets (5 L) with 4 windows (5 × 1.5 cm) • Using bait mixture: 150 g banana/pineapple + 2 g yeast + 2 g fipronil in 1 L water • Hanging traps at 1.5 m height on poles; 1 trap/ha • Using nanomatrix lures for 6–8 months of longevity.	• Root feeding of Imidacloprid 17.8 SL @ 1 ml + 1 ml water per palm. • Spot application of the following insecticides was effective: Spinosad 2.5 SC @ 5 ml/L water (0.013%) Indoxacarb 14.5 EC @ 2.5 ml/L water (0.04%)
d) Black headed caterpillar (*Opisina arenosella*)	• Improving overall palm health by applying balanced fertilizers and organic manure • Avoiding the use of broad-spectrum insecticides to protect natural enemies	• Cutting and burning the heavily infested and dried outermost 2–3 leaves to prevent pest spread	• Augmentative release of stage-specific parasitoids: *Goniozus nephantidis* @ 20/palm (larval parasitoid) *Elasmus nephantidis* @ 49 per 100 pre-pupae (prepupal parasitoid) *Brachymeria nosatoi* @ 32 per 100 pupae (pupal parasitoid)	• Spraying 0.05% diclorvos on under surface of leaves is recommended.
e) White grub (*Leucopholis coneophora*)	• Repeated ploughing of coconut basins once a month from September	• Daily hand-picking of adult beetles during the first 2 weeks of the	• Soil application of entomopathogenic nematodes (*Steinernema*	• Root zone drenching with 15 L solution/palm during May–June and Sept–Oct using:

Pest	Cultural Control	Mechanical Control	Biological Control	Chemical & Botanical Control
	to January (4–5 times) to expose grubs to predators and sunlight • Applying neem cake @ 5 kg/palm to promote root regeneration	southwest monsoon (May–June), especially during evenings	*carpocapsae*) @ 1.5 billion IJ/ha at 5–10 cm depth in interspaces	Chlorpyrifos 20 EC @ 2.5 ml/L Imidacloprid 17.8 SL @ 0.27 ml/L Bifenthrin 10 EC @ 5.0 ml/L
f) Coreid bug, (*Paradasynus rostratus* Dist.)	• Crown cleaning to destroy eggs and immature stages of the pest	• Removal of infested tender buttons	• Encouraging natural predators like the weaver ant (*Oecophylla smaragdina*) • Promote egg parasitoids: *Chrysochalcissa oviceps, Gryon homeoceri*	• Spraying azadirachtin 10,000 ppm (Nimbecidene) @ 0.004% (4 ml/L) on 1–5 month-old coconut bunches. • In severe outbreaks, spraying lambda-cyhalothrin 5% EC @ 1 ml/L on pollinated bunches
g) **Slug caterpillars (***Contheyla rotunda, Parasa lepida, Darna nararia)*	• Maintaining proper irrigation and soil nutrition to help palms recover from defoliation.	• Installation of light traps in endemic areas to monitor adult moths and reduce their population	• Conserving and promoting natural parasitoids like *Eurytoma tatipakensis, Euplectromorpha natadae* and *Secodes narariae*	• For the management of the pest during the outbreak season, chemical control using Spinosad 0.1% is recommended.
h) Rodents *(Rattus rattus wroughtoni*)	• Maintaining cleanliness in the garden by removing fallen fronds and plant residues regularly.	• Installing G.I. sheet bands (40 cm wide) around the trunk at 2 m height to prevent climbing.	• Use of natural predators to control rodent populations.	• Applying bromadiolone 0.005% poison bait blocks (10 g each) in the crown of 1 in every 5 palms, twice at a 12-day interval.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed monthly newsletter

Article ID : 05/VIII/15/0825

DESI COW OR EXOTIC BREEDS: WHICH'S BETTER FOR INDIAN DAIRY INDUSTRY?

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Abstract

India's dairy sector plays a crucial role in providing nutrition and livelihood, with both indigenous and exotic cow breeds contributing to milk production. Desi breeds like Gir and Sahiwal offer resilience, low-input costs and A2 milk, while exotic breeds such as Holstein Friesian and Jersey are known for higher milk yields but require intensive care. Hence critical comparison has been made by considering factors like milk yield, adaptability, disease resistance and sustainability. It also explores crossbreeding as a strategy to balance yield and resilience, while emphasizing the need to conserve native germplasm. The region-specific, sustainable dairy models that integrate desi breed conservation and informed crossbreeding to support long-term dairy development.

Keywords: Desi cows, exotic breeds, milk yield, sustainability and dairy farming

Introduction

India's status as the world's leading milk producer is largely supported by its vast and diverse cattle population. Over the decades, a shift in breeding practices has been observed, with the introduction of high-yield exotic breeds to meet growing demand. Despite their productivity, exotic breeds often struggle to adapt to Indian climatic conditions, raising questions about their suitability. In contrast, desi cow breeds have evolved naturally in India, thriving in diverse agro-climatic zones. This article explores the comparative advantages and limitations of both indigenous and exotic breeds, aiming to determine the most sustainable and efficient model for Indian dairy farming.

Characteristics of Desi Breeds

Indigenous breeds such as Gir, Sahiwal, Tharparkar, and Red Sindhi are well-suited to India's diverse climate and traditional farming systems. They are hardy, require minimal inputs, and have high disease resistance (Choudhary & Singh, 2020; Singh & Chauhan, 2019). Their milk, which contains A2 beta-casein protein, is often considered more nutritious and digestible. Desi cows also support sustainable agriculture by providing organic manure and biopesticides through dung and urine.

Figure-1 : Sahiwal breed

Figure-2 : Tharparkar breed

Features of Exotic Breeds

Exotic breeds like Holstein Friesian, Jersey, and Brown Swiss were introduced to increase milk output. While they produce 15–30 litres of milk per day, they demand high-quality feed, veterinary care, and controlled environmental conditions. Their milk generally contains A1 protein, which some studies suggest may not be as easily digestible. These breeds are more prone to tropical diseases and heat stress, limiting their long-term sustainability in India.

Figure-3 : Holstein Friesian

Figure-4 : Brown Swiss

Table-1 : Performance comparison between Indigenous and Exotic Dairy Breeds

Parameter	Desi Breeds	Exotic Breeds
Milk Yield	Moderate	High
Feed Cost	Low	High
Climate Suitability	Excellent	Poor to Moderate
Veterinary Needs	Low	High
Longevity	High	Lower
Milk Type	A2 (healthier)	Mostly A1

Crossbreeding as a Balanced Strategy

To balance productivity and adaptability, India has promoted crossbreeding programs using breeds like Karan Fries and Frieswal. These crossbreeds aim to combine the milk yield of exotic breeds with the resilience of indigenous ones. Success depends on scientific breeding practices, regional suitability, and farmer education. However, over-reliance on crossbreeds without conserving desi gene pools may risk long-term genetic erosion.

Sustainability and Economic Viability

Desi breeds are more cost-effective for small and marginal farmers due to their lower feed and maintenance costs. They align better with organic and natural farming practices. Exotic breeds may offer higher returns in commercial setups but often incur high input costs and veterinary expenses (Kumar & Prasad, 2021; NDDB, 2022). Policymakers and dairy cooperatives need to support region-specific solutions, integrating both breed types to optimize productivity and sustainability.

Conclusion

The debate between desi and exotic breeds is not solely about milk quantity but about long-term viability and adaptability. Indigenous breeds hold immense potential for sustainable dairy farming in India, especially in low-input systems. While exotic breeds can support high-output dairies under controlled conditions, their success is limited by environmental challenges. Moving forward, India must adopt an inclusive approach that prioritizes desi breed conservation, promotes responsible crossbreeding, and supports smallholder farmers. Such a strategy will strengthen the dairy sector and contribute to nutritional security, rural income, and environmental sustainability (Vohra, 2023).

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Article ID : 05/VIII/16/0825

DIGITAL INNOVATIONS AND USAGE BY AQUAFARMERS IN INDIA

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Introduction

In recent years, aquaculture in India has grown significantly, becoming an important sector for food production, rural employment, and economic development. This development has had a particularly positive impact in rural areas, improving livelihoods and encouraging sustainable farming practices. Previously, many aquafarmers faced challenges such as a lack of disease control knowledge and timely support. However, with the widespread adoption of smartphones and digital infrastructure, mobile applications have emerged as effective tools for providing timely information, resources, and expert guidance to aquafarmers (ICAR, 2021).

Matsya Setu App

The Matsya Setu app, developed by the ICAR-Central Institute of Freshwater Aquaculture (CIFA), was released on July 6, 2021, by the Ministry of Fisheries, Animal Husbandry, and Dairy. This app is intended to provide training and guidance on aquaculture techniques. It provides educational videos, quizzes, and access to aquaculture professionals. Topics include water quality management (pH, temperature control, etc.), species-specific culture methods, and sustainable farming practices, making it a comprehensive digital learning tool (ICAR, 2021; PIB, 2021).

Matsya Sathi App

Aqua Doctors created the Matsya Sathi app, which was released in East Midnapore, West Bengal, on March 23, 2025. Its main objective is to provide aquafarmers with timely advice on fish health management. Additionally, the app gives users access to real-time market data and allows them to connect with local fish seed suppliers. Because of this, the platform is advantageous, particularly for small-scale aquafarmers looking to improve farm operations' efficiency and productivity (Matsya Sathi, 2025).

Rangeen Machhli App

On September 12, 2024, the Union Minister of Fisheries introduced the Rangeen Machli App, which focusses on ornamental fisheries, as part of the Pradhan Mantri Matsya Sampada Yojana (PMMSY). The "Find Aquarium Shops" feature, which assists users in finding ornamental fish stores in their area, is one of the app's primary features. Promoting ornamental aquaculture and increasing market accessibility for entrepreneurs and hobbyists are the goals of this initiative (GK Today, 2024).

Crab Farming App

India's first digital platform devoted to mud crab aquaculture is the crab farming app. It provides guidance on managing water quality, stocking, feeding, and the financial aspects of crab farming. States like West Bengal, Orissa, Tamil Nadu, and Andhra Pradesh are especially well-known for this specialised but high-value industry. The app helps to increase farmer incomes and sustainability in coastal aquaculture by using mobile technology to spread best practices and professional advice (GK Today, 2024).

Conclusion

The use of digital tools in Indian aquaculture represents a significant shift in how aquafarmers gain access to knowledge, markets, and professional support. Applications such as Matsya Setu, Matsya Sathi, Rangeen Machhli, and the Crab Farming App provide farmers with real-time, science-based guidance, helping to promote more efficient and sustainable aquaculture practices. Continued investment in digital infrastructure and localised content will help to strengthen this transition, increasing productivity and improving rural livelihoods throughout India.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/17/0825

FROM ROOFTOPS TO ROOT DROPS: REVOLUTIONIZING URBAN GARDENING

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Abstract
Rooftops to root drops takes a closer look at how drip irrigation is changing the way we grow food in cities. With more people living in apartments and limited ground space, terrace gardening has become a smart and sustainable option. This piece shows how using drip irrigation—where water slowly reaches the roots of each plant—makes rooftop gardens more efficient, saving water and effort while giving better results. It's about making gardening easier for city folks, turning unused terraces into green, productive spaces that bring nature back into our everyday lives.

Keywords: Drip Irrigation, Terrace Farming, Fertigation, Urban gardening

Introduction

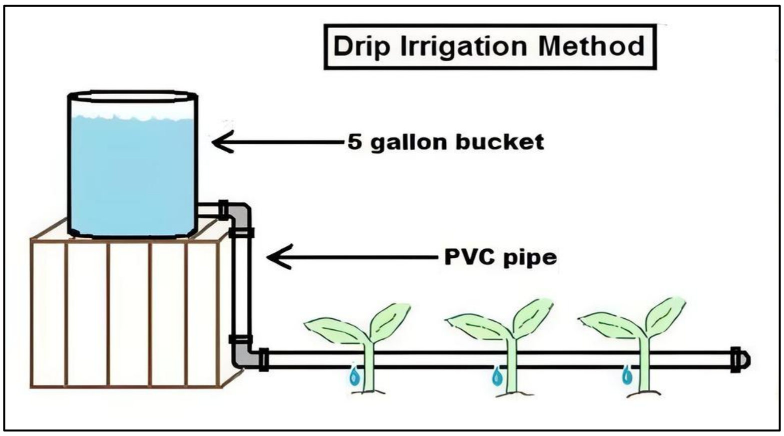
In today's world, where space is limited and the need for fresh, chemical-free, home grown vegetables are getting prioritised, rooftop farming/terrace farming has become a popular choice for many urban households. Turning rooftops into small farms not only helps in utilizing unused space but also brings us closer to nature. However, managing water effectively in terrace farming can be a challenge, especially in cities where water availability is limited. This is where drip irrigation comes in.

Drip irrigation is a smart watering method that slowly supplies water directly to the roots of plants through a network of tubes and emitters. It ensures that plants get just the right amount of water, reducing wastage and improving plant health. It's especially useful for terrace farms, where water needs to be carefully managed to avoid over-watering and leakage issues. Using drip irrigation in terrace farming not only saves water but also saves time and effort. It allows busy individuals to maintain their rooftop gardens with ease and helps in growing a variety of vegetables and fruits efficiently. With the right setup, even a small terrace can turn into a highly productive green space. This method supports sustainable living and offers a healthy, eco-friendly solution for growing food in urban settings.

Anatomy of drip irrigation in terrace farming

Drip irrigation is a smart and efficient way to water plants, especially in limited spaces like terrace gardens. Here's a breakdown of how the system works and the key parts involved:

1. Water Source : Every drip irrigation system begins with a water source. This could be a storage tank, water barrel, or even a tap. In terrace farming, a tank is often placed at a height to allow gravity-based flow, or a small motor pump is used for better pressure.



2. Filter Unit : The filter helps remove dust, sand, and other particles from the water before it flows through the pipes. This is important because small holes in drip emitters can easily get blocked without filtration.

3. Main Supply Pipe : A larger pipe (usually PVC or HDPE) carries the filtered water from the source to different parts of the terrace. It acts like the backbone of the system.

4. Sub-Main Pipes : These are smaller pipes that branch out from the main pipe to reach various grow bags, pots, or beds on the terrace. They help distribute water evenly to all areas.

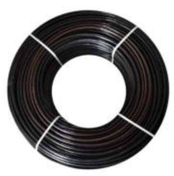
5. Drip Laterals / Tubes : These are thin, flexible pipes laid along the base of the plants. They contain small openings or emitters that release water slowly and directly at the root zone.

6. Drippers / Emitters : Drippers are fixed into the laterals and control the flow of water. They ensure that each plant gets just the right amount of water, drop by drop, reducing waste.

7. Control Valves : Valves help to regulate or stop the water flow to different sections. Some systems include a timer to automate watering at specific times of day, which is very convenient.

8. End Cap or Flush Valve : These are placed at the end of each pipe to close the system and allow cleaning. Regular flushing helps remove any dirt and keeps the system running smoothly.


Filter Unit


Main supply pipe


Drippers/Emitters


Control Valve


Sub main pipe


Drip laterals


End cap/Flush Valve

Final Setup of Drip Irrigation in Terrace Farming

Setting up of Drip Irrigation system in Terrace

The process begins with understanding the layout of the terrace and the arrangement of plants—whether in pots, grow bags, or raised beds. The entire setup revolves around a central water source, typically a water tank that can either be gravity-fed or connected to a small pump. This tank supplies water to a network of pipes that are carefully laid out across the terrace.

Mainline pipes run from the tank and branch out into smaller lateral pipes, which reach each individual plant. At each plant, a dripper or emitter is fixed near the base to deliver water directly to the root zone. These emitters release water slowly and consistently, drop by drop, making sure the plant receives just the right amount of moisture without any wastage. The number of emitters and their flow rate can be adjusted based on the water requirement of different plants.Before water enters the system, it is passed through a filter to prevent dust and debris from clogging the emitters. Once installed, the system is tested to ensure all drippers are functioning properly and water is reaching every plant. Regular maintenance, such as cleaning filters and occasionally flushing the pipes, keeps the system running smoothly.Drip irrigation in terrace farming reduces the effort of daily manual watering, saves water, and enhances plant health by preventing overwatering. It is an ideal solution for urban gardeners looking to manage their terrace gardens more efficiently while conserving natural resources.

Fertigation

Fertigation in terrace farming through a drip irrigation system is a smart and efficient way to nourish plants while saving time, water, and effort. By mixing water-soluble fertilizers directly into the drip lines, nutrients reach the plant roots gradually and precisely.

Schemes for establishing Drip Irrigation in Larger Area

- Pradhan Mantri Krishi Sinchai Yojana (PMKSY)
- PM-KUSUM Scheme

Merits and Demerits of Drip Irrigation

Aspect	Merits (Advantages)	Demerits (Disadvantages)
Water Efficiency	Delivers water directly to plant roots, which is vital in small terrace gardens.	Any leakage can lead to water damage to the building or stains on walls/floor.
Space Management	Compact and customizable can be set up around pots, grow bags, or raised beds easily.	Improper layout can make the terrace look cluttered or untidy.
Plant Health	Prevents fungal diseases by keeping foliage dry; promotes healthier growth.	If not maintained, clogged emitters can affect plant health or lead to under-watering.
Time & Effort	Automates watering - ideal for busy urban gardeners or working individuals.	Needs regular checks, especially in dusty or polluted city environments.
Weight Load	Lightweight tubing reduces additional load on terrace structures.	Overuse of water or leaks may increase structural stress if drainage is poor.
Water Conservation	Minimizes water usage - helpful in cities facing water shortages.	Requires filtered water; tap water with impurities may cause blockages.
Ease of Use	Once set up, very easy to use with timers or gravity-fed tanks.	Initial setup may be tricky for beginners without guidance or support.
Cost Factor	Long-term cost-effective as it reduces water bills and plant loss.	Initial investment (pipes, timers, filter) can be high for small terrace farmers.
Aesthetics	Neat piping can enhance the modern garden look.	Poorly installed systems can make the terrace look messy or unappealing.

Conclusion

Drip irrigation in terrace farming offers a smart, sustainable solution for urban agriculture by efficiently using limited space and water. It delivers water and nutrients directly to plant roots, reducing wastage, boosting yields, and minimizing labor through automation. While it requires some initial investment and maintenance, the long-term benefits like higher productivity and environmental sustainability make it a valuable choice for city dwellers. With growing awareness and government support, this method is transforming rooftops into vibrant, eco-friendly gardens.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/18/0825

ECO-FRIENDLY SILK: HOW SERICULTURE PROMOTES SUSTAINABLE FARMING

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Introduction

Silk, renowned for its luxurious texture and deep cultural roots, is now at the forefront of the sustainable textile movement. As global consumers increasingly seek eco-friendly alternatives, sericulture the cultivation of silkworms for silk has emerged as a model for sustainable agriculture, blending tradition, innovation, and environmental stewardship. This article explores how eco-friendly silk production supports sustainable farming, benefits rural communities, and addresses pressing ecological challenges.

Defining Eco-Friendly Silk

Silk distinguishes itself from other fibers through its natural, biodegradable properties and relatively low environmental impact when produced sustainably (Ogori *et al.,* 2022; Kundu *et al.,* 2024). Unlike synthetic textiles, silk decomposes naturally and does not contribute to microplastic pollution. Eco-friendly silk production is characterized by minimal chemical processing, with organic silk cultivated without synthetic pesticides or fertilizers, reducing soil and water contamination (Sharma & Singh, 2024). Mulberry, the primary host plant for silkworms, requires less water than cotton, and traditional silk rearing is less energy-intensive than synthetic fiber manufacturing (Kumar & Grześkowiak, 2023). The use of plant-based and mineral dyes, along with water recycling, further minimizes environmental harm (Wang *et al.,* 2022).

The Sustainable Sericulture Process: Mulberry and Silkworms

Sericulture begins with mulberry cultivation, which provides both food for silkworms and environmental benefits. Mulberry plantations prevent soil erosion, enhance soil structure, and enrich organic matter (Dinu & Muntean, 2025; Sharma & Singh, 2024). These plantations also support biodiversity by serving as habitats for various species and promoting ecological balance through organic farming practices. Silkworm farming efficiently converts mulberry leaves into valuable silk fiber with minimal inputs. Integrated pest management (IPM) and organic rearing methods reduce the need for chemical pesticides, protecting both the environment and farm workers (Chawla *et al.,* 2024).

Figure 1. Depiction of Nurturing Sustainability in Sericulture

Embracing a Circular Economy

Sericulture exemplifies circular economy principles by utilizing nearly all by-products. Silkworm pupae are used as animal feed or processed for oil, waste mulberry leaves and stems are composted to enrich soil, and cocoon shells are repurposed for biodegradable products, cosmetics, or spun silk fabric (Kumar & Grześkowiak, 2023). These practices minimize waste, create additional income streams, and enhance overall sustainability.

Innovations in Sustainable Silk Production

A significant innovation in sustainable sericulture is Ahimsa or "peace" silk, which allows moths to emerge naturally before silk is harvested, eliminating animal cruelty and supporting ethical textile production. While the resulting fiber is shorter, it retains the softness and durability of traditional silk and empowers rural communities, especially women artisans in Northeast India. Organic silk production, certified by standards such as GOTS, ensures environmental and social responsibility at every stage—from mulberry cultivation to silk processing. Organic silk avoids GMOs, synthetic fertilizers, and pesticides, supporting biodiversity and farmer well-being. Additionally, recycled silk, produced from waste silk fibers, and alternative plant-based silks (e.g., banana, pineapple, bamboo) are gaining popularity. These alternatives reduce pressure on traditional resources and utilize agricultural waste, supporting a zero-waste approach (Bansal & Kumar, 2025).

Environmental Benefits: Soil, Biodiversity, and Carbon Footprint

Mulberry plantations stabilize land, prevent erosion, and improve soil structure, making sericulture valuable for land rehabilitation and sustainable agriculture (Sharma & Singh, 2024; Dinu & Muntean, 2025). Sericulture also supports biodiversity by providing habitats for beneficial insects, birds, and other wildlife. Organic and IPM practices further protect local ecosystems and water bodies from contamination (Chawla *et al.,* 2024; Kundu *et al.,* 2024). The adoption of organic and IPM practices has led to lower chemical runoff, reduced farmer exposure to toxins, and enhanced ecosystem health (Ogori *et al.,* 2022; Chawla *et al.,* 2024). Sustainable silk production has a smaller carbon and water footprint compared to synthetic fibers and cotton. Mulberry requires less irrigation, and traditional silk rearing uses less energy than synthetic textile manufacturing (Kumar & Grześkowiak, 2023; Wang *et al.,* 2022). Sericultural waste is increasingly recycled into bio-composites, bioenergy, and other value-added products, further reducing the industry's ecological footprint (Bansal & Kumar, 2025; Department of Science & Technology, 2025).

Socio-Economic Impact: Employment and Rural Development

Sericulture generates significant rural employment, especially for women and marginalized groups. Over 60% of the workforce in silk-producing regions is female, making sericulture a powerful tool for women's empowerment and poverty reduction (Ogori *et al.,* 2022). By diversifying rural incomes and integrating with other agricultural activities, sericulture enhances the resilience of farming communities. Mulberry can be intercropped with food crops, livestock, or agroforestry, optimizing land use and income sources. Cooperatives, self-help groups, and local silk industries foster community development, support traditional knowledge, and ensure equitable benefit-sharing (Mathew *et al.,* 2024).

Challenges and Future Directions

Despite its advantages, sustainable sericulture faces challenges such as resource intensity in large-scale production, climate change impacts on mulberry and silkworms, and the need to scale up organic and cruelty-free practices (Dinu & Muntean, 2025; Kundu *et al.,* 2024). Continued policy support, research, and extension services are essential for promoting sustainable sericulture and supporting smallholder farmers (Department of Science & Technology, 2025).

Conclusion

Sericulture exemplifies how traditional agriculture can evolve to meet modern sustainability challenges. By embracing organic farming, ethical silk production, waste recycling, and community empowerment, eco-friendly silk offers a blueprint for sustainable farming and responsible luxury. As innovations continue and consumer awareness grows, silk is poised to remain a symbol not only of beauty and tradition but also of environmental stewardship and social progress.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/19/0825

ENTOMOPATHOGENIC FUNGI: A SUSTAINABLE BIOCONTROL STRATEGY AGAINST WHITEFLIES

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Introduction

Whitefly (*Bemisia tabaci*) is one of the most economically important insect pests of ornamental and vegetable plants including brinjal, chili, cotton, okra, potato, tomato, and tobacco throughout the world's tropical and subtropical climates. Among the 1,556 identified species of whiteflies globally, *B. tabaci* stands out as a major pest, significantly affecting vegetable and ornamental crops on an economic scale worldwide. The nymphs and the adults are damaging stages of whitefly as they feed directly on the plants, as well as act as vectors for various plant viruses. Whiteflies secrete sticky substance called honeydew, which reduces the rate of photosynthesis in plants. Chemical pesticides are commonly used to control whitefly populations but they are harmful to the environment as they possess health risk to users and consumers of farm produce and endanger the safety of non-target organisms. In recent years, there has been a growing focus among researchers on utilizing biological control agents, such as entomopathogenic fungi (EPF), as sustainable alternatives to chemical control methods of whiteflies.

What Are Entomopathogenic Fungi (EPF)?

Generally, the term EPF refers to the organisms that are pathogenic to insect pests. EPF infects insects externally, as opposed to chemical insecticides that target the insect's nervous system. The insect cuticle serves as a vital component in the infection process of EPF, acting as the primary channel for fungal entry. The fungal spores adhere to the insect's body, penetrate its cuticle, and develop inside. EPF proliferate irregularly within the insect hemocoel, eventually leading to hyphal colonization of the insect body. The insect's death results from a combination of factors: mechanical damage caused by EPF penetration, toxicosis due to fungal toxin production, and depletion of vital nutrients. The infection cycle is then continued when the fungus produces more spores, which subsequently spread to other insects.

Common entomopathogenic fungi, including *Beauveria bassiana*, *Metarhizium anisopliae*, *Isaria fumosoroseus*, *Ashersonia* spp., and *Verticillium lecanii*, play a key role in the natural mortality of whitefly populations *B. tabaci* (Khan et al, 2012).

***Beauveria* spp:** It is one of the most commonly used EPF, and has been commercially developed as a microbial insecticide to control whiteflies. It is an important EPF which belongs to the class Deuteromycetes. It comprises various species such as *B. bassiana, B. amorpha, B. brongniartii*, and *B. calendonica*, with *B. bassiana* being the most prominent as EPF. The fungal growth on infected insects is a dense, white powder. Upon

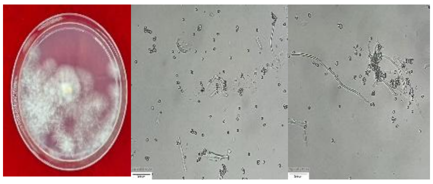

Fig 1. ***B. bassiana*** **culture and conidia**

fungal infection, a white layer of mycelium becomes visible, protruding from the insect's exoskeleton and giving rise to synnemata, the reproductive structures. Additionally, *B. bassiana* has been shown to increase plant defenses to abiotic stresses, as well as antagonistic to plant pathogens. The commercial formulation of *B. bassiana*-based myco-insecticides is comparatively more stable and effective against lepidopteran insect pests (Sandhu et al., 2012). According to a recent study, *B. bassiana* isolates are also effective against corn earworm, different aphid species, stored pests.

***Lecanicillium* spp:** The *Lecanicillium* genus includes vital insect-pathogenic fungi that were previously grouped under the single species *Verticillium lecanii* (Faria et al., 2010). These fungi belong to the order Hypocreales and commonly known as white halo fungus. Key species of *Lecanicillium* fungi include *L. lecanii, L. attenuatum, L. longisporum*, *L. nodulosum*, and *L. muscarium*. These fungi are highly effective against various insect pests, particularly sucking pests such as aphids, whiteflies, mealybugs, and scales. It has been proved to be pathogenic to all developmental stages of whitefly. Dead whiteflies mummify due to fungal infection. Compatibility experiments of *L. lecanii* and other chemical insecticides such as imidacloprid, buprofezin, and teflubenzuron showed promising outcomes in reducing the population of different stages of whitely.

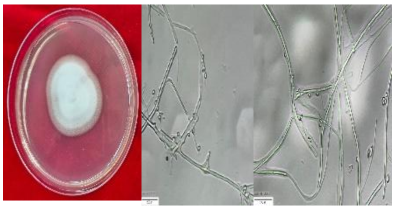

Fig 2. L. lecanii culture and conidia

***Metarhizium* spp:** It has been shown that *M. anisopliae* can potentially infect all developmental stages of different whitefly species. Fungal growth of *Metarhizium* spp. on the outside of infected insects is very dense and green in color, so it is commonly referred to as the green muscardine fungus. This fungus acts by penetrating the insect's exoskeleton, proliferating within its body, and eventually causing the host's death through nutrient depletion and the production of toxins. Depending on the environmental conditions, sporulation (the process where the fungi produce reproductive structures, called spores or conidia) may or may not be visible on the surface of insects that are killed by the fungus. It is also effective against pests such as termites, grasshoppers, aphids, and beetles

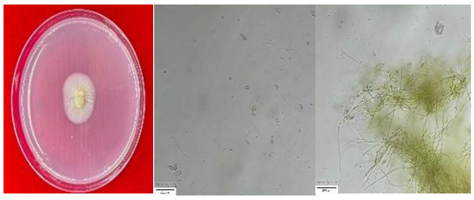

Fig 3. *M. anisopliae* culture and conidia

***Isaria* spp**: The *Isaria* genus, previously referred to as *Paecilomyces*, encompasses significant entomopathogenic fungi (EPFs). The key species within the *I. genus* are *I. farinosa* and *I. fumosorosea*. It is one of the most important natural enemies of whiteflies, and it can cause an epizootic in whiteflies in greenhouse and open field environments. Currently, *I. fumosoroseus* is globally distributed and can infect a broad range of pests in agricultural and forest area. Commercial demand to investigate bioproducts based on *I. fumosoroseus,* due to its capacity to cause natural epizootics on several insect pests, is therefore compelling. Although many studies on the potential of *I. fumosoroseus* against whiteflies have been carried out, they have been largely focused on the mortality and infections of nymphs and adults of whitefly.

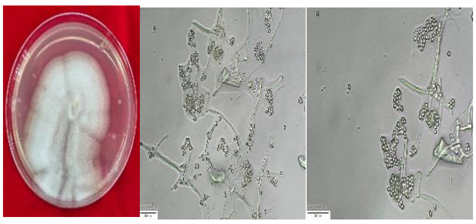

Fig 4. *Isaria* spp. culture and conidia

Generally, EPF should be applied at the first appearance of whitely. Typically, it takes 6 to 14 days after the first spray to see control. Application rates, frequency, spray coverage and insect numbers impact the speed at which acceptable control is achieved. These are most effective when used early, before high insect populations develop. In most instances, second spray should also be done based on whitefly population. The best results from EPF applications occur in the early morning or late evening application as the UV rays are not directly affecting the organism. EPF do have the most efficacy in humid conditions, so weather conditions will be important when deciding when to apply the fungus. The addition of wetting agents can help spores stick to insect bodies more effectively.

Life cycle and mode of action:

The EPF life cycle coincides with the insect host's developmental stages and the current environmental conditions. Typically, the life cycle consists of a parasitic phase, which lasts from host infection until death, followed by a saprophytic phase, which begins after the host dies. Broadly, the infection process of all EPF involves spore attachment to the cuticle, hyphal germination on the insect's surface, integument penetration by hyphae, fungal growth within the hemocoel, and eventually, the host's death (Tahira, 2014).

The life cycle of entomopathogenic fungi (EPF) begins with spore adhesion to the insect's body, followed by spore germination. The germ tube's mechanical and enzymatic action results in penetration into the insect. Once within, the spores form yeast-like propagules by budding development, which disseminate throughout the hemocoel. Along with toxin production, EPF disrupts the insect's metabolic activities by infiltrating its organs, resulting in death. The fungus then colonizes the cadaver, reverting to its characteristic hyphal form during the saprophytic phase, which is characterized by sporulation. Spores spread passively from diseased cadavers to new hosts.

Advantages of Using EPF Against Whiteflies

One of the primary advantages of employing EPF as a biopesticide is its safety for the environment. EPF decomposes naturally in the environment without causing long-term harm, in contrast to chemical pesticides that can pollute soil and water and leave residues on food. they are also a good tool for sustainable agriculture because they don't threaten beneficial insects like bees, butterflies, and natural predators of whiteflies. To improve pest management techniques, EPF can also be combined with other biological control techniques like the use of predatory beetles and parasitoid wasps.

EPF also reduces the chances of whiteflies developing pesticide resistance, which is another important advantage. Additionally, most EPF have no waiting period, so they can be sprayed on harvest day.

Challenges in Using EPF

- **Environmental Factors:** Successful EPF require environmental factors. Fungal spores require a vast degree of humidity and moderate temperatures to germinate and infect insects. In hot or dry environments, they will be far less effective. Equally, UV from sunlight can degrade fungal spores, and keep them from living on a plant surface.
- **Slow Action Compared to Chemical Insecticides:** EPF takes several days to eradicate whiteflies, in comparison to synthetic insecticides that kill pests within few hours. This slower

mode of action means farmers must apply EPF in advance and use them as part of a long-term strategy rather than expecting immediate results.

- **Formulation and Storage:** The shelf life of EPF is very less because fungal spores are sensitive to storage conditions and may lose viability when exposed to unfavourable temperatures or humidity levels. To address this, researchers are developing oil-based and microencapsulated formulations that improve the stability and persistence of EPF in the field.
- **Cost and Adoption Barriers:** EPF-based products might be more expensive than traditional pesticides. Further, farmers have not used biologically-based control, especially EPF-based, and may not want to adopt them because they require specific handling and application. Raising awareness and providing education on the proper use of EPF could increase adoption of EPFs in agricultural systems.

Integrating EPF with Other Pest Management Strategies

EPF have the greatest effectiveness when used as part of Integrated Pest Management (IPM). Their efficacy will be enhanced when used with biological and cultural controls. In addition to EPF, natural predators may be released, such as parasitoid wasps (Encarsia formosa) and lady beetles, which can provide additional control of whiteflies. An effective use strategy would be to apply an EPF to initiate the infection process and reduce the whitefly load and, if necessary, spray a selective insecticide. This approach would allow the fungal spores to infest and spread before treatments that would be hostile to the fungal spores.

IPM strategies can incorporate habitat management and flowering plants to attract beneficial arthropods capable of naturally regulating whitefly populations. The use of reflective mulches and trap crops may help reduce whitefly infestations and promote the efficacy of fungal biopesticides.

The Future of EPF in Whitefly Control

EPF seems to have a promising future as a whitefly control strategy. Their potency is being boosted by advances in biotechnology and fungal formulation processes, making them more suitable for general agricultural use. In addition, scientists are working to develop genetically modified fungus strains that are more virulent and climate-adaptable.

Apart from causing direct infection, some entomopathogenic fungi (EPF) also generate secondary metabolites, chemical compounds that can increase their efficacy in killing insects. Certain fungal species, such as *Beauveria bassiana,* produces beauvericin, an insecticidal toxin, that was reported to weaken and kill insects much more effectively. Others produce repellents that could potentially lower infestations over time, as they discourage whiteflies from feeding on, and depositing eggs, on treated plants. In addition, there are reports that some fungal metabolites decrease insects' immune systems, making them more susceptible to fungal infections. Future research is projected to develop these secondary metabolites into more potent bioinsecticides, through rapid activity and improved efficacy under challenging environmental conditions.

The awareness of farmers regarding the benefits of biological control, the use of EPF is required to increase. Adoption strategy may be further augmented by grants, subsidization, and training programs supported by the government. Entomopathogenic fungi are a sustainable, natural, effective means of managing whiteflies and reducing reliance on chemical pesticide use, even if there is still some uncertainty. Both these fungi and their secondary metabolites may contribute increasingly to keeping crops safe and the environment healthy as agriculture continues to evolve.

Conclusion

Entomopathogenic fungi (EPF) provide a sustainable and eco-friendly solution for managing whiteflies, offering an effective alternative to chemical pesticides. Fungal species such as *B. bassiana*, *L. lecanii*, *M. anisopliae*, and *I. fumosorosea* have demonstrated significant potential in controlling whitefly populations. Despite their benefits, the effectiveness of EPF can be influenced by environmental factors such as humidity, temperature, and UV exposure, requiring careful application and formulation improvements. The future of EPF-based biopesticides lies in advanced formulations, improved delivery systems, and the use of secondary metabolites to enhance their insecticidal properties. Additionally, farmer adoption is crucial for widespread use, which can be facilitated through agricultural extension programs. Farmers can reduce their reliance on chemical pesticides by including EPF into IPM strategies, so promoting a more sustainable and ecologically friendly method of pest control.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/20/0825

EXPORT BANS ON RICE AND WHEAT: CAUSES, CONSEQUENCES AND GLOBAL RIPPLE EFFECTS

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Abstract

Export bans on staple grains like rice and wheat most notably by India, the world's largest rice exporter has sent shockwaves through global food markets. India's 2023 ban on non-basmati rice exports, covering over 40 per cent of global rice trade, triggered a surge in international prices, strained supply chains and heightened food insecurity in import dependent regions, particularly Africa and Asia. These disruptions were compounded by weather shocks and tight supplies from other exporters. The ripple effects highlight the fragility of global food systems and the far-reaching consequences of unilateral trade restrictions on essential commodities.

Keywords: Export ban, Food security, Global prices and Ripple Effects

Introduction

India, the world's largest exporter of rice and the second-largest producer of wheat, plays a pivotal role in the global food grain market. Its decisions to impose export bans or restrictions on these staples reverberate worldwide. The government's primary motivation for such measures is to curb rising domestic food prices and ensure adequate food availability for its vast population. However, these protective policies have complex implications for global food security, commodity prices, international trade relations, and the livelihoods of millions of farmers and consumers worldwide.

Causes of export bans on rice and wheat in India

India's export bans on rice and wheat are primarily driven by domestic concerns:

- **Rising Domestic Prices and Inflation:** Inflationary pressures on essential food items like rice and wheat have historically led to political and social unrest in India. For example, in 2022 and 2023, retail rice prices surged due to poor summer harvests exacerbated by the El Niño weather phenomenon, prompting the government to impose export restrictions to stabilize prices domestically.
- **Food Security and Stockpile Management:** India's government aims to maintain buffer stocks to ensure food security. When procurement by government agencies falls short, as seen in the 2021-22 wheat marketing season, export bans are used to prevent depletion of stocks. Currently, India holds record-high stockpiles of rice (59.5 million tonnes) and wheat (nearly 37 million tonnes), reflecting both production surpluses and export curbs.
- **Crop Failures and Weather Variability:** Erratic weather patterns, including droughts and floods, have affected crop yields, particularly the kharif rice crop harvested in October, leading to precautionary export restrictions until new harvests replenish supplies.

- **Political Considerations:** Export restrictions often coincide with election cycles or periods of heightened political sensitivity to food inflation, as domestic food price stability is crucial for political stability.

Nature of export restrictions

India's export restrictions have varied in scope and intensity:

- **Wheat Export Ban:** Since May 2022, India banned all wheat exports, including premium varieties like durum and soft bread wheat, with exceptions only for government-approved shipments to countries facing food security crises.
- **Rice Export Controls:** India has imposed a ban on non-basmati white and broken rice exports, while allowing exports of basmati and parboiled rice, albeit with duties (e.g., a 20% export duty on non-basmati rice). The ban on non-basmati rice, which accounts for a significant portion of India's rice exports, has effectively halved global shipments from the country.
- **Stock Reporting and Monitoring:** The government mandates weekly declarations of rice and wheat stocks by traders and processors to closely monitor supply and prevent hoarding.

Immediate Global Impacts

India's export bans have triggered significant disruptions in global food markets:

- **Price Volatility and Inflation:** The sudden reduction in rice and wheat exports from India, which accounts for roughly 40 per cent of global rice exports, has tightened global supplies and pushed prices upward. Studies have documented price spikes in global rice markets following India's non-basmati rice export ban in 2023. The price increases exacerbate inflationary pressures in importing countries, particularly in Asia and Africa.
- **Supply Chain Disruptions:** Import-dependent countries, especially in South Asia, Africa, and the Middle East, face shortages and must scramble to find alternative suppliers, often at higher costs. This leads to increased food insecurity and social unrest in vulnerable regions.
- **Trade Tensions and WTO Scrutiny:** India's prolonged export restrictions have drawn questions from WTO member states including the US, Canada, Australia, and Japan, which have sought clarity on the duration and rationale for the bans, highlighting concerns over compliance with international trade rules.

Long-term and ripple effects

The ripple effects of India's export bans extend beyond immediate market disruptions:

- **Global Food Security Risks:** Export bans by major producers like India reduce the availability of staple grains on the global market, undermining food security in low-income, import-reliant countries. This can lead to increased hunger and malnutrition, particularly in regions already vulnerable to climate shocks and conflict.
- **Incentives for Diversification:** Importing countries may seek to diversify their sources of staple grains or invest in domestic production to reduce dependence on a few exporters, potentially reshaping global agricultural trade patterns.
- **Impact on Farmers and Domestic Markets:** While export bans aim to protect domestic consumers, they can depress prices received by farmers, reducing their incomes and

disincentivizing production. Conversely, stockpiling and storage expansion efforts by the Indian government aim to stabilize farmer incomes and ensure supply.

- **Geopolitical Implications:** Food export restrictions can exacerbate geopolitical tensions, especially when countries compete for limited supplies. Export bans during times of global crises such as the Russia-Ukraine warcompound food insecurity and can lead to diplomatic strains.

India's strategic responses and future outlook

India is actively managing its grain stocks and export policies to balance domestic needs with global responsibilities:

- **Expanding Storage Capacity:** The Indian government plans to invest $15 billion to increase grain storage capacity by 70 million tonnes over five years, aiming to store 100 per cent of grain production and better manage supply fluctuations
- **Selective Export Permissions:** While maintaining broad bans, India has allowed limited wheat exports to select countries under government-to-government agreements to meet humanitarian and food security needs.
- **Policy Flexibility:** Export restrictions are expected to remain in place at least until the October kharif rice harvest and possibly through March 2025 for wheat, reflecting cautious management amid inflationary pressures and climate uncertainties.
- **International Engagement:** India faces ongoing pressure at WTO forums to justify export restrictions and align policies with global trade norms, requiring diplomatic balancing acts.

Conclusion

India's export bans on rice and wheat are a double-edged sword—while they serve to protect domestic food security and control inflation, they also disrupt global food markets, elevate prices, and threaten food security in vulnerable countries. The global ripple effects underscore the interconnectedness of food systems and the challenges of balancing national interests with global responsibilities. Moving forward, enhanced international cooperation, transparent policy communication, and investments in resilient agricultural systems are essential to mitigate the adverse impacts of export restrictions and safeguard food security worldwide.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/21/0825

EMPOWERING FISH FARMERS: ROLE OF KVKs IN FISHERIES EXTENSION

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Introduction

The fisheries sector plays a crucial role in enhancing food security, rural livelihoods and economic development in India. As the demand for aquatic products grows, empowering fish farmers with scientific knowledge and model practices becomes vital for sustainable growth. Krishi Vigyan Kendra (KVKs) established in Puducherry in 1974 and now numbering 732 across the country (ICAR, 2024), serve as key district-level institutions that bridge the gap between research and field-level application in agriculture and allied sectors including fisheries. The KVKs are designed to provide need-based, skill-oriented vocational training to farmers, field-level extension workers and aspiring entrepreneurs (Prasad *et al.,* 1987). In fisheries, KVKs play a transformative role by disseminating advanced aquaculture techniques, transfer, thereby empowering fish farmers to adopt innovative and sustainable practices for enhanced productivity and income.

Basic Concepts of a Krishi Vigyan Kendra (KVKs)

Krishi Vigyan Kendra (KVKs) are grassroots-level institutions established by the Indian Council of Agricultural Research (ICAR) to transfer agricultural and allied sector technologies to rural communities. Designed as knowledge and resource centres, KVKs serve farmers, fishermen, rural youth and extension personnel through a unique “learning by doing” approach that emphasizes hands-on, experience-based training. One of the fundamental principles of KVKs is promoting technical literacy through practical learning, without requiring formal education, thus ensuring inclusivity. These centres cater primarily to practicing farmers, fishermen and employed extension workers as well as those seeking self-employment. Unlike traditional institutions, KVKs do not follow a uniform syllabus; instead, each centre customizes its training programs based on the specific agro-climatic conditions, natural resources and developmental needs of the local area. This flexible demand-driven approach makes KVKs highly effective in building local capacities, fostering rural entrepreneurship and promoting sustainable agricultural and fisheries development.

Fundamental Principles of KVKs

1) **Agricultural production as the prime goal**: The main focus is to enhance production in agriculture and allied sectors, including fisheries.
2) **Work-experience as the main training method**: Training is imparted through practical, hands-on experiences and enhancing learners to acquire technical skills irrespective of their literacy level.

3) **Priority to weaker sections**: The programme gives special emphasis to training and empowering the weaker and marginalized sections of society, such as small farmers, fishermen, women and rural youth.

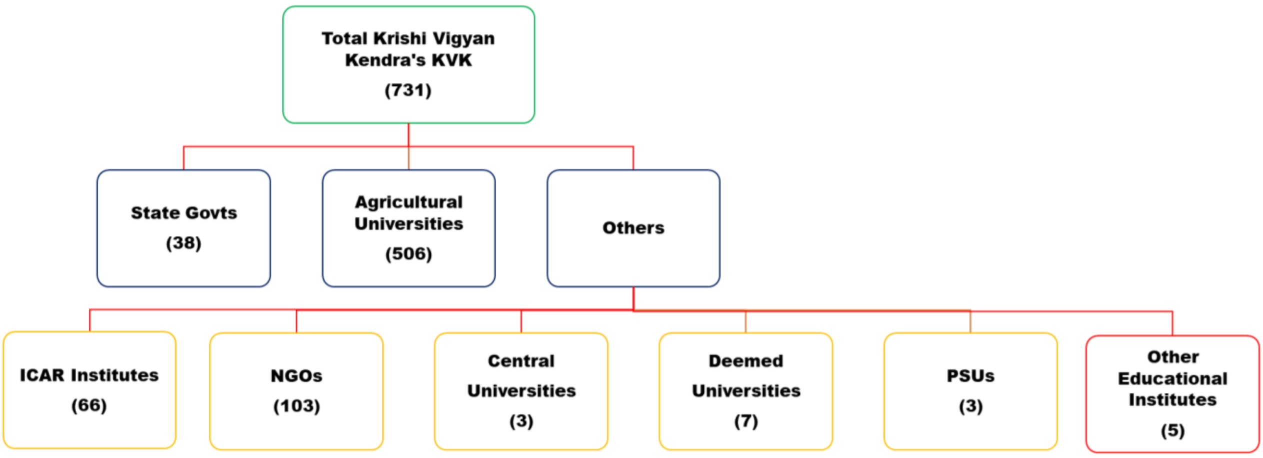
The main objective of KVKs is to provide robust training support and capacity building, aiming to bring about significant breakthroughs in agricultural and fisheries production.

Objectives of KVKs

1) Conduct survey to identify local resource inventory and training needs.
2) Compile and adapt recommended district practices for training and extension.
3) Organize need-based, production-oriented short and long-term training for all target groups, prioritizing weaker section.
4) Establish farm science clubs in schools and villages to promote scientific farming among youth.
5) Develop campus demonstration units for practical training and transfer of technical knowledge.
6) Offer training facilities to teachers and vocational agriculture students.
7) Provide basic education to rural illiterates and school dropouts for better farming and citizenship.
8) Collaborate with organizations to extend training in homemaking, nutrition, home crafts and cottage industries for integrated rural development.

Structure of KVKs

The organizational structure of Krishi Vigyan Kendra (KVKs) is designed to ensure effective outreach and implementation of agricultural technologies at the grassroots level across India. As illustrated in the diagram there are a total of 731 KVKs distributed nationwide (Global Agriculture, 28 January 2025).



These KVKs operate under three main categories of administrative control:

1. **State Governments:** A total of 38 KVKs are managed by State Governments. These centres work in close collaboration with respective state agricultural departments, aligning extension activities with state-level priorities.
2. **Agricultural Universities:** The largest number of KVKs, 506 are operated under various Agricultural Universities. These institutions play a major role in linking scientific research

and academic expertise directly with farming communities, ensuring the effective transfer of technology and innovations.

3. **Others:** The remaining KVKs are managed by different other organizations that further diversify the outreach and resource base. This category includes:
    - **ICAR Institutes:** 66 KVKs
    - **Non-Government Organizations (NGOs):** 103 KVKs
    - **Central Universities:** 3 KVKs
    - **Deemed Universities:** 7 KVKs
    - **Public Sector Undertakings (PSUs):** 3 KVKs
    - **Other Educational Institutes:** 5 KVKs

This decentralized and collaborative structure, involving government bodies, universities, research institutes, NGOs and educational establishments, ensures that KVKs have wide reach and can cater to the diverse agricultural needs of different regions effectively. By leveraging the strengths of these host organizations, KVKs are able to provide location specific solutions, relevant training and hands-on demonstrations to farmers, including those in the fisheries sector for sustainable and enhanced productivity.

Role of KVKs in Fisheries-Related Activities

Krishi Vigyan Kendra (KVKs) play a vital role in advancing fisheries activities and strengthening the abilities of fish farmers. They begin by assessing the specific requirements of local communities and then develop tailored fisheries training programs focused on improving technical expertise. KVKs organize demonstrations on harvest and post-harvest methods while promoting the use of enhanced feeding practices, breeding advancements and effective water management. In addition, they offer practical on-site support and advisory services to help farmers implement these improvements successfully. Regular monitoring and evaluation of outcomes provide insight into gains in productivity and income. The incorporation of feedback ensures that training content and technology transfer remain relevant and effective. This comprehensive approach is instrumental in fostering sustainable development of fisheries at the local level.

Flowchart: Sequential approach of KVKs in promoting fisheries technologies

Krishi Vigyan Kendra (KVKs)
↓
Identify Need of Fish Farmers and sector
↓
Design & Organize Fisheries-Specific Capacity Building and Training Programs
↓
Conduct Demonstrations on Harvest & Post Harvest Technologies
↓
Disseminate Improved Technologies & Best Practices (Feed, Breeding, water management)
↓
Provide On-Field Support & Advisory services to Fish Farmers
↓
Monitor Adoption of Technologies & Evaluate Impact on Yield and Income
↓
Feedback Loop to Improve Training & Technology Dissemination

Success Stories: Here are some brief case studies of 3-4 farmers or SHGs who benefited from KVK fisheries initiatives.

S. No	Case Study	Personal Details	Activity/ Innovation	Support Received	Outcomes/Achievements	Practical Utility
1.	Suseela Devi value Added product via SHG	**Name:** Suseela Devi **Age**: 38 **Education:** 5th pass **SHG**: Shagun SHG (2008) **Role**: President **Place:** Jhankat Village, US Nagar	Value-added product making (herbal gulal, Snacks, Dehydrated items, Sweets)	KVK Kashipur (training in 2009), Bhoomi Project (SHG formation)	• Net profit of Rs. 5500 Association with handicrafts ministry • Rs. 2000-4000/month income for group members	• Economic upliftment • Income via traditional knowledge (ITK) • Employment for 14 women • Effective marketing • Role model development
2.	Udaiveer Singh-Fish Farming	**Name:** Udaiveer Singh **Age:** Young Farmer **Education:** Not mentioned **Place:** Brahmnagar Village, Kashipur	Fish culture (6 species), 0.5-acre pond developed	KVK Kashipur (training, technical support)	• 1420 kg fish produced • Gross income: Rs.92,820 • Net income: Rs.71,920 • More than 12 pond created locally • Awarded "Kisan Shri"	• Income diversification • Motivation to nearby farmers • Rural employment • Use of scientific aquaculture • Reduced youth unemployment
3.	Parveen Devi Handicraft via SHG	**Name:** Parveen Devi **Age:**31 **Education:**5th Pass **SHG:** Priyanka SHG (2008) **Role:** Member **Place:** Jhankat Village, US Nagar	Indigenous handicrafts using ITK and local resources	KVK Kashipur (2009 training), Bhoomi project (loan Rs.6583)	• Rs.2000-4000/month income • Exhibition of products at various events • Tie-up with Handicrafts Ministry	• Economic upliftment • Local resources & ITK used • Employment for group • Market linkages • Women empowerment

S. No	Case Study	Personal Details	Activity/ Innovation	Support Received	Outcomes/Achievements	Practical Utility
4.	Frozen Pea Hub-U.S. Nagar	Multiple farmers in US Nagar Supported by Govt. & private sectors	Commercial pea cultivation & frozen/dehydration processing	KVK Kashipur, Dept. of Horticulture, MOFPI, State Govt.	• 20,000+ ha under pea cultivation 35% of India's frozen pea demand met 11 IQF units established • Rs.11702 lakhs invested	• Massive employment generation • Farmer to entrepreneur shift • Strong backward linkages • Agro-industry boost • Export opportunities

Conclusion

Krishi Vigyan Kendra (KVKs) have emerged as pivotal institutions in transforming India's fisheries sector by equipping fish farmers with the necessary knowledge, skills and technologies for sustainable and profitable aquaculture. Functioning as decentralized extension arms of the Indian Council of Agricultural Research (ICAR), KVKs effectively bridge the gap between scientific research and field-level application through hands-on training, need-based diversification and community empowerment are evident in numerous success stories of individual farmers and self-help groups across the country. As India advances toward the goals of Blue Revolution 2.0 and integrated rural development, sustained support for KVKs in terms of infrastructure, collaboration and digital outreach will be essential to furthering their impact on fisheries extension, food security and rural livelihoods.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/22/0825

FROM FLOW TO GLOW: USING SMART METERS TO TRACK WATER USE IN REAL TIME

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Introduction

Agriculture consumes approximately 70% of the world's freshwater resources, making efficient irrigation management critical for global food security and sustainable water use. With growing populations and climate change intensifying water scarcity, traditional irrigation practices relying on manual monitoring and scheduled watering no longer meet modern agricultural demands. Smart water meters represent a revolutionary advancement in precision agriculture, leveraging Internet of Things (IoT) technology, advanced sensors and wireless communication to provide real-time monitoring of irrigation water consumption patterns.

Unlike conventional flow meters that offer only basic volumetric measurements, smart agricultural water meters deliver comprehensive data including flow rates, pressure variations, soil moisture correlation and precise application timing. This technology enables farmers, irrigation districts and agricultural cooperatives to optimize water distribution detect system malfunctions immediately and implement precision irrigation strategies based on actual crop water requirements rather than generalized scheduling approaches.

The integration of smart meters into agricultural water management systems transforms farming from reactive irrigation scheduling to proactive, data-driven water application. When irrigation lines rupture or emitters become clogged during critical growing periods, smart meters detect anomalies instantly, alerting farm managers before crop stress occurs or significant water volumes are wasted. This technological evolution supports sustainable intensification of agriculture while preserving precious water resources for future generations.

Modern smart meters designed for agricultural applications incorporate specialized features including weather station integration, soil moisture sensor connectivity and crop growth stage algorithms that automatically adjust irrigation recommendations based on plant physiological needs. These systems enable farmers to achieve optimal crop yields while minimizing water consumption, reducing production costs and enhancing environmental sustainability across diverse agricultural landscapes.

Beyond Monitoring: Creating Water-Efficient Agricultural Systems

Smart meter technology in agriculture extends far beyond simple flow measurement, creating comprehensive water management ecosystems that integrate multiple data sources for optimal irrigation decision-making. Real-time consumption data combined with weather forecasts, soil conditions and crop development stages enables precision irrigation scheduling that maximizes water use efficiency while maintaining crop quality and yield potential.

Agricultural operations equipped with smart meter networks can monitor individual field zones, greenhouse sections or crop varieties separately, identifying specific areas requiring adjusted irrigation strategies. This granular control enables farmers to implement deficit irrigation techniques, optimize fertigation timing and prevent over-irrigation that leads to nutrient leaching and root zone problems. Smart meters generate extensive datasets that support advanced agricultural analytics, helping farmers predict irrigation requirements based on seasonal patterns, crop phenology and local weather conditions. Machine learning algorithms analyze historical consumption data alongside yield records to identify optimal irrigation strategies for specific crops, soil types and climatic conditions, continuously improving recommendations through adaptive learning processes.

Irrigation cooperatives and water districts benefit significantly from aggregated smart meter data that reveals regional consumption patterns, peak demand periods and distribution system inefficiencies. This comprehensive information enables improved water allocation planning, infrastructure maintenance scheduling and equitable distribution among member farms during water shortage periods.

Integration Challenges and Infrastructure Demands

Implementing smart meter technology across agricultural irrigation systems presents unique challenges distinct from municipal water applications. Many farming operations rely on decades-old irrigation infrastructure including concrete-lined canals, steel pipelines and mechanical distribution systems that require significant modifications to accommodate digital monitoring equipment. Communication networks supporting agricultural smart meters must maintain reliability across vast rural areas often lacking robust cellular coverage or internet connectivity. Solar-powered communication systems and long-range wireless protocols become essential for remote field installations where conventional power sources are unavailable or unreliable.

The harsh agricultural environment presents additional technical hurdles including exposure to pesticides, fertilizers, extreme temperatures and physical damage from farming equipment. Smart meters designed for irrigation applications require enhanced durability, chemical resistance and weatherproof enclosures that protect sensitive electronic components while maintaining measurement accuracy over extended operational periods. Battery longevity becomes particularly critical in agricultural applications where devices may operate continuously throughout growing seasons in remote locations with minimal maintenance access. Advanced power management systems incorporating solar charging and ultra-low-power communication protocols are essential for achieving multi-year operational lifespans required for practical farm implementation.

Implementation Barriers

Economic Considerations for Agricultural Applications

Initial investment costs for comprehensive smart meter deployment across large agricultural operations can be substantial, particularly for smallholder farmers operating with limited capital resources. The economic justification becomes complex when balancing technology costs against potential water savings, yield improvements and reduced labor requirements for irrigation monitoring and system maintenance. Cost-benefit analysis for agricultural smart meters must consider multiple factors including crop values, water pricing structures, energy costs for pumping and long-term infrastructure durability. High-value specialty crops may justify sophisticated monitoring systems, while field crops with lower profit margins require more cost-effective solutions that provide basic monitoring capabilities without extensive analytical features.

Financing mechanisms specifically designed for agricultural technology adoption, including equipment leasing programs, cooperative purchasing arrangements and government subsidy programs, play crucial roles in making smart meter technology accessible to diverse farming operations. These financial instruments help distribute implementation costs over multiple growing seasons while providing immediate operational benefits.

Technical Challenges in Agricultural Settings

Agricultural irrigation systems present unique technical challenges including variable water quality, seasonal operational patterns and integration with existing farm management systems. Smart meters must maintain accuracy across different water sources including wells, surface water and recycled irrigation return flows that may contain sediments, chemical additives or biological materials.

Calibration and maintenance requirements become more complex in agricultural environments where access to specialized technical support may be limited. Smart meter systems designed for farming applications must provide user-friendly interfaces, self-diagnostic capabilities and robust technical support networks that can respond quickly during critical irrigation periods when system failures could result in significant crop losses. Integration with existing farm management software, precision agriculture platforms and automated irrigation control systems requires standardized communication protocols and data formats that facilitate seamless information exchange. The lack of universal standards across different manufacturers can create compatibility issues that complicate system integration and data management processes.

Social Acceptance and Knowledge Transfer

Adoption of smart meter technology among agricultural producers varies significantly based on farm size, crop types, technological familiarity and previous experiences with precision agriculture tools. Effective technology transfer requires demonstration programs, peer-to-peer learning opportunities and ongoing technical support that address specific regional farming practices and crop requirements. The assumption that detailed irrigation data automatically improves water management has proven overly optimistic without accompanying education programs that teach farmers how to interpret consumption patterns, identify optimization opportunities and implement data-driven irrigation scheduling. Creating meaningful behavioural change requires comprehensive training programs that connect technology capabilities with practical farming applications.

Extension services play critical roles in facilitating smart meter adoption through field demonstrations, economic analysis assistance and technical troubleshooting support. These programs must address diverse farming communities including different cultural backgrounds, educational levels and economic circumstances to ensure equitable access to water conservation benefits.

Future Outlook

The agricultural smart meter industry continues evolving toward greater standardization, improved interoperability and enhanced integration with broader precision agriculture ecosystems. Industry collaboration through agricultural technology consortiums and standards organizations is developing common protocols that facilitate data exchange between different manufacturers and software platforms. Emerging technologies including artificial intelligence, satellite imagery integration and IoT sensor networks promise to enhance smart meter capabilities by providing comprehensive environmental monitoring that supports increasingly sophisticated irrigation management decisions. These integrated systems will enable autonomous irrigation scheduling based on real-time crop stress indicators, weather predictions and soil condition monitoring.

Cost reductions through improved manufacturing processes, increased competition and technology maturation will make smart meter systems accessible to smaller farming operations and developing agricultural regions. Simplified installation procedures and reduced maintenance requirements will further accelerate adoption across diverse agricultural sectors.

Conclusion

Smart water meters offer transformative potential for agricultural water management through real-time irrigation monitoring, immediate system fault detection and data-driven water use optimization. While implementation faces technical, economic and social challenges, the benefits including improved crop yields, reduced water consumption and enhanced sustainability justify continued investment in agricultural water monitoring technology.

Success requires collaborative efforts between technology developers, agricultural extension services, irrigation districts and farming communities to address implementation barriers while maximizing conservation benefits. The transition from traditional irrigation scheduling to intelligent, responsive water management represents a fundamental shift toward resource-efficient agriculture that can meet growing food demands while preserving water resources for future generations. This technological evolution will be essential for achieving global food security in an increasingly water-constrained world.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/23/0825

GHINGHARU: A VALUABLE MEDICINAL AND ECOLOGICAL SHRUB OF THE HIMALAYAS

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Introduction

Ghingharu botanically known as *Pyracantha crenulata* M. Roem. Syn. *Crataegus crenulata* Roxb., is a thorny, bushy perennial shrub belonging to the family Rosaceae. People in hill states of India, call it *ghingharu*, but it is also known by other names like Himalayan firethorn, Nepalese firethorn, Indian hawthorn and *chota seb*. This species is native to the temperate regions of the Himalayas and thrives at altitude ranging from 900 to 2,400 meters (Weber, 2003). This perennial shrub is primarily found growing around villages in wastelands and in the cultivated fields of Uttarakhand (Krishna *et al*., 2024). *Ghingharu* is well adopted in Uttarakhand with potential medicinal benefits, however, not exploited yet commercially. It can be used as a rootstock for apple and pear. It can also be used for ornamental purpose due to its fast growing habit, dense foliage, showy flowers with colorful berries and hence can add beauty to the landscape (Jaiswal *et al*., 2024).

Importance and uses

Ghingharu fruits are edible and rich in natural sugars, antioxidants, vitamins (A, C, E, B_{12}) and minerals like calcium and potassium (Singh *et al*., 2018). Its leaves are used to make herbal tea (Kunkel 1984), and both the fruits and flowers are valued for their heart-protective, blood pressure-lowering and circulatory benefits. The ripe fruits are eaten fresh and a mixture of the dried fruit powder with yoghurt is used in the treatment of blood dysentery (Singh *et al*., 2018).

***Ghingharu* plant in forest areas**

Traditionally used in Ayurveda, *ghingharu* treats heart ailments, hypertension, and dysentery. It contains bioflavonoids with antioxidant, anti-inflammatory, diuretic, sedative and immunomodulatory effects. Clinical studies have shown its potential to reduce cholesterol and improve heart function (Negi *et al*., 2009).

Ecologically, *ghingharu* is important for soil conservation. Its deep root system helps in preventing erosion and landslides, making it suitable for planting on fragile hill slopes (Gamble 1972). Conventionally this plant is exploited by the local inhabitants for the fencing of agricultural fields and for making tool handles for agricultural implements.

Table 1: Biochemical constituents of *ghingharu*

S.N.	Biochemical constituent	Quantity
1.	Protein	5.13 ± 0.04%
2.	Flavonoids	2.9 ± 0.4 %
3.	Moisture	60.10 ± 0.15 %
4.	Carbohydrate	24.88± 0.16%
5.	Ash	1.50 ± 0.08%
6.	Organic matter	98.50± 0.22%
7.	Total nitrogen	0.82 ± 0.07%
8.	Soluble ash	74.71 ± 0.08%
9.	Insoluble ash	25.29 ± 0.05%
10.	Crude fibre	7.40 ± 0.09%
11.	Crude fat	1.00 ± 0.25 %
12.	Calcium	3.08 ± 0.021 mg/100 g
13.	Magnesium	1.4 ± 0.02 %
14.	Sodium	1.00 ± 0.2 %
15.	Potassium	1.43 ± 0.05 %
16.	Vitamin A	289 ± 0.07 IU/100 g
17.	Vitamin B_1	0.50 ± 0.04 mg/100 g
18.	Vitamin B_2	17.7 ±1.10 mg/100 g
19.	Vitamin C	55 ± 3.03 mg/100 g
20.	Vitamin E	272 ± 5.0 mg/100 g

(Source: Saklani and Chandra, 2014, Singh *et al*., 2018)

Botanical Description

Taxonomy: The systematic classification of this plant is as shown below:-

Kingdom - Plantae
Phylum - Anthophyta
Class - Magnoliopsida
Order - Rosales
Family - Rosaceae
Genus – *Pyracantha*
Species – crenulata

Habitat: The perennial shrub *ghingharu* is found throughout China and the Himalayas, ranging from Sutlej to Bhutan at elevations of 900-2400 meters, reaching heights of up to 2-5 m. It can be found along streams, on the banks of river tributaries, on roadsides, in pine and Quercus woods, and in mixed forests (Osmaston, 1926).

Leaves: Dark green in colour, 2.5–4.0 cm in length, and 1.0–2.2 cm in width with tapering ends with smooth surface. The name "crenulata" comes from the distinctive feature of *Pyracantha crenulata* leaves, which are characterized by their finely toothed margins that give them a crenulated appearance.

Inflorescence: Compound corymb with many white flowers in it.

Flowers: Flowering occurs in the months of April to May, flowers are white coloured containing five sepals and five petals. The flower cluster emerges at the tips of the branches.

Fruits: Fruiting occurs during the months of July to September in Uttarakhand. Fruit is pome, orange-red in colour when ripe. The immature fruits are green in colour.

Seeds: Each berry generally contains five triangular brown-colored seeds; sometimes three or four seeds are observed, and the seeds are covered with a hard seed coat.


Leaves


Flowers


Immature Fruits


Ripe fruits

Propagation techniques:

There is a lack of knowledge about propagation of *ghingharu,* as it is a forest or wasteland shrub and is not in cultivation yet. Its seeds have hard seed coat, requiring pre-germination treatments. Being a temperate region fruit, it might require cool climate for its germination. Exposure of seed in cool moist soil in earlier winter might provide favourable temperature, humidity and available moisture for seed germination and application of growth regulators like GA_3 might increase germination percentage. Krishna *et al*. (2024) reported that seeds treated with 150 ppm GA_3 and sown on 15th November under open field conditions recorded the best seedling growth with respect to both shoot and root characteristics. Daudi and Pandey (2015) attained highest seed germination (60%) when seeds soaked in normal water for 12 hours, sown in a 1:1 sand and soil mixture under mist chamber condition. They also reported that the best rooting response (74%) was achieved with 5000 ppm IBA in stem cutting. Mani *et al*. (2022) also reported that IBA treatment exhibited best results with respect to root and shoot characteristics of semi hardwood cuttings.

Ecological Significance

This shrub plays a vital role in supporting Himalayan wildlife and maintaining ecosystem balance. Its nutrient-dense berries are an essential food source for birds and ape, particularly in the autumn and winter when food is scarce. The flowers attract a number of pollinators such as bees and butterflies, which help in pollination and seed production, contributing to plant diversity and ecological stability. The soil binding capacity of *roots* helps in preventing soil erosion by binding the soil, especially on slopes and degraded areas. In degraded or fragmented landscapes, it may act as a natural wildlife corridor by allowing birds and small animals to move between habitats which supports gene flow, species survival and the overall health of the ecosystem. Uttarakhand is currently facing challenges in increase in fellow and uncultivated lands due to migration. Such lands can be put under the cultivation of this hardy crop which will be ecologically beneficial as it will provide a support to fragile fellow lands and will prevent landslides by checking soil erosion. This will increase production and rural people and unemployed youth can be trained to prepare its marketable and healthy products. Thus, it will help in employment generation and it will also reduce the uncontrolled exploitation and harvesting of this crop from forests and other natural habitats.

Value addition potential

It holds great potential for the development of nutraceutical and pharmaceutical products due to its fruit being rich in bioactive compounds. These health-benefiting properties make it ideal for formulating a variety of value-added food products such as herbal drinks, jams, energy bars and fruit juice, powder etc. DIBER (DRDO) has developed a herbal beverage, “Hridayamrit”, from the fruit juice of *ghingharu* which is rich in vitamins, minerals, proteins and antioxidant.

Conclusion

Ghingharu is a valuable multipurpose shrub found in the Himalayan foothills. Due to its thorny nature, it also serves as an effective natural fence to protect crops from stray and wild animals. It adds aesthetic value to moist hill landscapes and has high commercial potential. While most of its population is currently wild, large-scale cultivation and systematic propagation could benefit both the environment and the local economy. Local communities can generate income by supplying leaves and fruits as raw materials to the pharmaceutical and nutraceutical industries. To fully utilize its potential, efforts must focus on mass propagation, organized planting, genetic conservation, and further research into its diversity and uses. Most of the land in Uttarakhand hills has become degraded and fellow due to problem in cultivation of agronomic and other horticultural crops which need attention and care for growing. Wild animal menace has also increased the fellow land area in Uttarakhand. Villages having such lands can be put under cultivation of *ghingharu*, for their fruits and leaves. Their fruits and leaves can be supplied to ayurvedic and pharmaceutical companies and it might become source of income to rural people of hills. This will also reduce the pressure of over exploitation of this medicinally important shrub growing on wastelands and forests.

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Article ID : 05/VIII/24/0825

HARNESSING THE BLUE ECONOMY: A SUSTAINABLE FUTURE FOR INDIA'S FISHERIES SECTOR

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Introduction

As the world increasingly looks to the oceans not just as a source of food, but also for solutions to climate change, economic growth, and employment, the concept of the Blue Economy has taken center stage. At its core, the Blue Economy advocates for the sustainable use of ocean resources to benefit both people and the planet. The concept emerged prominently during the United Nations Conference on Sustainable Development (Rio+20) held in Rio de Janeiro in 2012 (UNCTAD, 2014). Since then, the term "Blue Economy" has been used in various ways, often interchangeably with similar terms such as "ocean economy" or "marine economy," though these are not always clearly defined. In a concept paper, the United Nations broadly described the Blue Economy as an ocean-based economy that promotes "the improvement of human well-being and social equity, while significantly reducing environmental risks and ecological scarcities" (UN, 2014).

In India, with a long coastline of over 7,500 kilometres, the country is uniquely positioned to benefit from the Blue Economy model. It also has a vast network of rivers, lakes, reservoirs, wetlands and estuarine, making inland fisheries a vital part of its aquatic resources (Mohanty *et al.*, 2017). The nation boasts rich marine biodiversity, supports over four million fishers and fish workers, and contributes significantly to global fish production. India is already the third-largest fish-producing country in the world and the second-largest in aquaculture (NFDB, 2024). Fisheries and aquaculture contribute to food and nutritional security, generate livelihoods for coastal and rural communities, and earn valuable foreign exchange through exports. Despite these strengths, the sector faces pressing challenges such as overfishing, habitat degradation, climate change impacts, and market fluctuations. However, these challenges also present opportunities for transformation. With strategic planning, technological innovation, ecosystem-based management, and community involvement, India can further scale up its fisheries sector. Aligning its policies with Blue Economy principles can help ensure environmental sustainability, resilience to climate risks, and inclusive economic growth, particularly for vulnerable fishing communities. Embracing this path can also strengthen India's global leadership in sustainable ocean stewardship. This article explores how India can answer these questions by embracing the principles of the Blue Economy, a model that values sustainability as much as development, ensuring that both the ocean and the people who depend on it thrive together.

The blue economy advantage

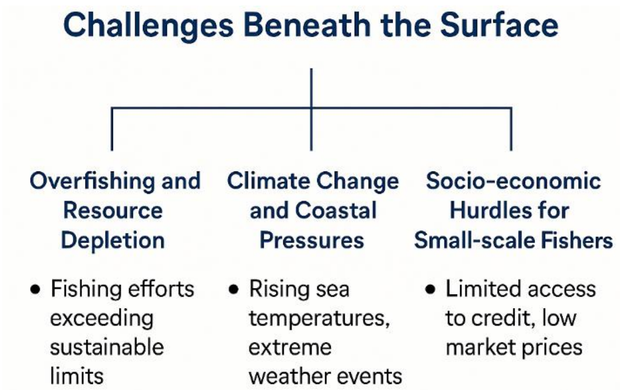
The Blue Economy offers a transformative approach to harnessing ocean resources in a sustainable and inclusive manner. It goes beyond traditional marine activities by stressing the balance between economic growth, environmental sustainability, and social equity. Sectors such as fisheries, aquaculture, marine biotechnology, coastal tourism, renewable ocean energy, and maritime transport are key pillars of this model.

The focus areas of the Blue Economy include:

1. Promotes responsible utilization of marine resources without degrading the ecosystem.
2. Boosts GDP through sectors like fisheries, aquaculture, tourism, and maritime transport.
3. Creates jobs in coastal and marine industries, especially for rural and coastal communities.
4. Enhances fish production sustainably, ensuring a stable protein source for the population.
5. Encourages the use of advanced technologies like AI, GIS, and marine biotechnology.
6. Supports nature-based solutions like mangrove restoration and coastal protection to combat climate change.
7. Protects marine life and habitats through sustainable practices and protected areas.
8. Attracts public and private investments in green infrastructure and ocean-based industries.

Challenges beneath the surface

While the promise of the Blue Economy brings hope, several challenges continue to threaten the health of India's fisheries sector and the well-being of its coastal communities.



Overfishing and resource depletion

India's marine ecosystems are under increasing pressure from overfishing. In many coastal zones, the fishing effort has been moving on the sustainable limits, leading to the decline of fish stocks. This is driven by destructive fishing practices, unregulated harvests, and the growing number of mechanized boats contribute to the rapid depletion of marine resources (Shakouri et al., 2010). As traditional fishers struggle to compete, the ecological balance of coastal waters is at risk, posing a serious threat to both biodiversity and livelihoods.

Climate change and coastal pressures

Hot issue on rising sea temperatures, changing ocean currents, coastal erosion, and extreme weather events are already affecting fish breeding cycles and migration patterns. Fishermen communities are witnessing dwindling catches and loss of fishing days due to rough seas (Islam et al., 2020). Additionally, coastal development, pollution, and habitat destruction (like the loss of mangroves and coral reefs) further weaken the resilience of marine ecosystems. Climate change acts as a multiplier, deepening existing vulnerabilities in the fisheries sector.

Socio-economic hurdles for small-scale fishers

Small-scale fishers, who form the backbone of India's fisheries, face a host of socio-economic challenges such as low fish catch rates, limited access to credit, difficulty in adopting modern technology, lack of cold storage or value addition facilities, and low market prices, making it hard for them to sustain their livelihoods in the future. Additionally, gender knowledge gaps and limited livelihood development opportunities affect women involved in post-harvest activities, including fish drying, processing, and marketing. These challenges are compounded by limited awareness of government support schemes, low participation in value addition activities, and declining interest among young women in fisheries-related livelihoods.

Towards sustainable fisheries

To secure the future of India's fisheries, a shift towards sustainable and inclusive practices is essential. This involves a combination of policy action, technological innovation, and community involvement.

Responsible fishing practices

Encouraging regulated fishing limits, such as restricting trawling within 5 nautical miles from the shore, along with monitoring boats, enforcing seasonal bans, and promoting the use of eco-friendly gear, helps protect fish stocks and marine biodiversity (Islam et al., 2017). Educating fishers about sustainable harvesting methods ensures that resources are preserved for future generations.

Technology and Modernization

Introducing modern fishing equipment and digital monitoring systems such as online payment facilities for fishers and access to real-time information on industry trends can significantly enhance efficiency. The development of cold storage facilities and value addition technologies also helps reduce post-harvest losses. Technology plays a crucial role in improving market access, particularly through digital marketing, enabling fishers to receive fair prices via online platforms and traceability systems.

Community participation

Engaging local communities in decision-making ensures that policies reflect ground realities. Strengthening cooperatives, promoting women's involvement, and encouraging youth participation help build a resilient and inclusive fisheries sector.

Policy support: A Step in the Right Direction

Highlighting national schemes and regulatory frameworks aimed at strengthening sustainable fisheries management. In that, the Pradhan Mantri Matsya Sampada Yojana (PMMSY) and related marine policies in promoting responsible fishing practices and infrastructure development. Such as the PMMSY, launched in 2020. The scheme is specifically aimed at enhancing fish production, improving fishers' incomes, and ensuring sustainable management of fisheries resources across the country. It has a total estimated investment of ₹20,050 crores over a period of five years (2020–2025), making it the largest-ever investment in India's fisheries sector (NFDB, 2024).

Key Focus Areas of PMMSY and marine policy:

- Promoting responsible fishing practices
- Infrastructure development
- Digital and technological advancements
- Capacity building and training
- Marine Fishing Regulation Acts (MFRA) of Coastal States
- National Policy on Marine Fisheries, 2017
- Implementation of FAO Guidelines and International Agreements

Role of Stakeholders: Fishers, Scientists, NGOs, Consumers

Sustainable fisheries management trusts on collaboration between fishers, scientists, NGOs, and consumers. Fishers play a key role by adopting responsible practices and sharing traditional knowledge. Scientists provide data and innovations to guide policies and improve fishing methods. NGOs support communities through training, advocacy, and promoting sustainable practices. Consumers influence market demand by choosing responsibly sourced seafood and supporting eco-friendly initiatives.

Building awareness and collaboration

Building awareness and collaboration among all stakeholders is essential. This includes joint platforms for knowledge sharing, public campaigns to promote sustainable seafood, aligning policies with community needs, and ensuring transparent information flow. Together, these efforts help protect marine resources while supporting the livelihoods of fishing communities.

Conclusion:

The harnessing the Blue Economy offers India a unique opportunity to balance economic growth with environmental sustainability in its fisheries sector. By promoting responsible fishing practices, investing in modern technologies, supporting coastal communities, and encouraging collaboration among fishers, scientists, NGOs, and consumers, India can ensure both the health of its marine ecosystems and the well-being of millions who depend on them. A sustainable future for India’s fisheries lies in embracing policies and actions that value long-term ecological balance alongside economic progress, securing prosperity for present and future generations.

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ISSN : 2583-0910
Agri-India TODAY
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Article ID : 05/VIII/25/0825

INTERACTION AND MECHANISM OF DIFFERENT PRODUCTION FACTORS IN IFS

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Introduction

In economics, *factors of production* are the essential building blocks used to create the goods and services we rely on every day. These inputs—land, labor, capital, and entrepreneurship—combine to transform resources into finished products. This relationship between what we put in (inputs) and what we get out (outputs) is called the *production function*.

Among these, the *primary factors of production* stand out:

- Land, which covers all natural resources and the physical space where production takes place—above and below the ground.
- Labor, meaning human effort and skill, including the knowledge and expertise that make up human capital.
- Capital, referring to the tools, machinery, and equipment that aid production without being part of the final product.
- Entrepreneurship, the driving force that brings the other factors together, takes risks, and organizes production activities.

Alongside these four classical factors, modern production also relies on the *Four M's*: Management, Machines, Materials, and Money. Together, these resources power the entire process that turns ideas and raw materials into the products that shape our lives.

Historical Perspectives on Production Factors

Classical Economic Theory:

- The term "factors of production" emerged after the classical period and is not found in classical literature.
- **Classical economists** like Adam Smith and David Ricardo focused on physical resources: land, labor, and capital.

Land: Natural resources used in production.

Labor: Human effort, both physical and mental, used in production.

Capital: Human-made goods like machinery and buildings used in production.

Physiocracy: In French Physiocracy, the main European school of economics before Adam Smith. French Physiocrats viewed the production process as interactions among classes: farmers, landlords, and merchants.

- **Farmers**: Produce goods using land and crafts.
- **Landlords**: Consume goods and produce nothing.
- **Merchants**: Trade goods for imports.

Marxian Economics:
Marx considered the "elementary factors of the labour-process" or "productive forces". Marx's factors of production include **labour**, the **subject of labor** (natural resources), and the **instruments of labor** (tools and infrastructure). Labour, according to Marx, is the key factor, as it transforms resources into goods and services. Marx distinguished between "labour" (work done) and "labour power" (capacity to work).

Austrian and Neoclassical Economics:
Austrians and neoclassicals view the entrepreneur's time as crucial, influencing the output when combined with other factors. Neoclassical economists built on classical factors but developed new theories of value and distribution, adding distinctions like:

- **Fixed Capital**: Long-term assets like machinery and buildings.
- **Working Capital**: Short-term assets like inventories.
- **Financial Capital**: Money invested in the business

Modern Additions:
Newer theories have expanded factors of production to include:

- **Human Capital**: Skills and education.
- **Intellectual Capital**: Knowledge and innovation.
- **Social Capital**: Networks and relationships.
- **Technological Progress**: Improvements in efficiency and productivity, often unexplained in traditional models but essential for economic growth

Classical economics focused on physical resources, while modern theories incorporate human and intellectual contributions. The importance of each factor varies among schools, with debates on the primary factor of production.

Entrepreneurship as a Factor of Production

- Entrepreneurs combine land, labor, and capital to generate profits.
- They are often seen as innovators, creating new products and production methods.
- In market economies, entrepreneurs operate independently; in planned economies, central planners decide the allocation of resources for maximum public benefit.
- Entrepreneurship can also be seen in bureaucracies and government through "political entrepreneurs" who navigate and innovate within these systems.

Non-Tangible Forms of Capital
Human Capital : Represents skills and knowledge gained through education and training. Essential for economic growth and solving trade paradoxes. Modern economic theories emphasize the importance of education in economic development.

Intellectual Capital : Pertains to intellectual property like music, and literature. Protected by copyrights, patents, and trademarks. The Information Age has shifted focus from traditional factors to knowledge, collaboration, and time quality.

Social Capital : Involves trust, shared values, and social networks that facilitate economic activity. Cannot be individually owned but is crucial for societal peace and economic transactions. Individual social capital includes reputation and "goodwill," which can be transformed into economic gains depending on social networks and connections.

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Natural Resources : Ayres and Warr (2009) are among the economists who criticize orthodox economics for overlooking the role of natural resources and the effects of declining resource capital.

Energy : Energy can be seen as individual factor of production, with an elasticity larger than labour.

Production Theory : Production theory examines the economic process of transforming inputs into outputs. This includes all activities involved in creating a good or service, such as manufacturing, storing, shipping, and packaging. Production can be broadly defined as all economic activities except consumption, encompassing everything before the final purchase.

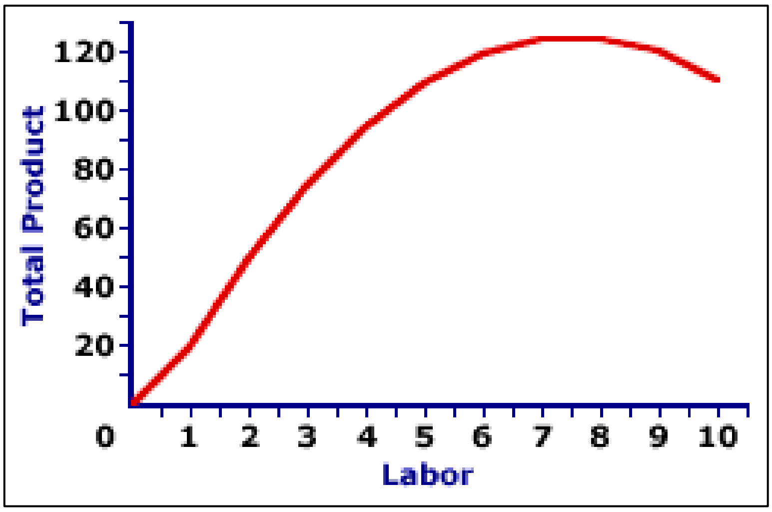
Characteristics of Production:
1. **Quantity**: The amount of goods or services produced.
2. **Form**: The specific nature or type of goods or services created.
3. **Distribution**: The temporal and spatial availability of goods or services.

Production Process: It increases the alignment between the demand for goods and services and their quantity, form, size, shape, and distribution.

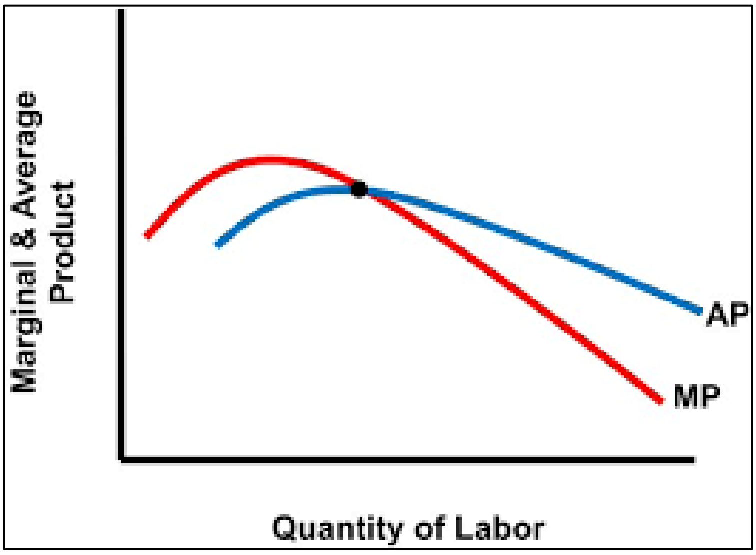
Production Outputs
Total Product (TP):
- The total output produced by a given amount of a variable input.
- Represented as a total product curve showing output levels at different input levels.

Average Product (AP):
- The output per unit of input.
- Calculated by dividing total production by the number of input units (e.g., if 10 employees produce 50 units, the AP is 5 units per employee).

Marginal Product (MP):
- The additional output resulting from a one-unit increase in the variable input.
- Can be discrete (a specific additional unit) or continuous (infinitesimal changes).
- Represented by the marginal product curve, derived from the slope of the total product curve.



Total Product curve



Average and Marginal physical Product curve

Total Product, Average Product, and Marginal Product Curves in Integrated Farming Systems (IFS)

1. Total Product (TP) Curve

Definition: Total Product refers to the total output produced by a certain amount of input in the production process.

Example in IFS: Consider a farm integrating crop production with goat rearing. Let's assume the farm uses different amounts of goat manure (input) to improve soil fertility and increase crop yield.

- **Input:** Amount of goat manure (e.g., 10 kg, 20 kg, 30 kg).
- **Output:** Total crop yield (e.g., 100 kg, 200 kg, 300 kg).

TP Curve Example:

- With 10 kg of goat manure, the total crop yield is 100 kg.
- With 20 kg of goat manure, the total crop yield increases to 200 kg.
- With 30 kg of goat manure, the total crop yield reaches 300 kg.

The TP curve plots the total crop yield against the amount of manure used, showing how output increases with input.

2. Average Product (AP) Curve

Definition: Average Product is the output per unit of input. It is calculated as Total Product divided by the amount of input used.

Formula: AP=Total Product \ Quantity of Input

Example in IFS: Using the previous example of manure:

- With 10 kg of manure, TP = 100 kg. AP = 100 \ 10 = 10 kg of crop per kg of manure.
- With 20 kg of manure, TP = 200 kg. AP = 200 \ 20=10 kg of crop per kg of manure.
- With 30 kg of manure, TP = 300 kg. AP = 300 \ 30=10 kg of crop per kg of manure.

The AP curve shows how the average output per unit of input remains constant or changes as more input is used.

3. Marginal Product (MP) Curve
Definition: Marginal Product is the additional output generated by using one more unit of input.

Formula: MP=ΔTotal Product (TP) \ ΔQuantity of Input

Example in IFS: Continuing with the manure example:
- **From 10 kg to 20 kg of manure:**
    - Increase in TP = 200 kg - 100 kg = 100 kg
    - MP = 100 \ (20−10) =10 kg of crop per additional kg of manure.
- **From 20 kg to 30 kg of manure:**
    - Increase in TP = 300 kg - 200 kg = 100 kg
    - MP = 100 \ (30−20) =10 kg of crop per additional kg of manure.

The MP curve illustrates how the additional output changes as more input is added, showing the incremental benefit of each additional unit of input.

Relationships Between Total, Average, and Marginal Products
Marginal Product (MP) influences **Average Product (AP)**:
- When AP is rising, MP is greater than AP.
- When AP is falling, MP is less than AP.
- The MP curve intersects the maximum point on the AP curve.

Stages of Production:
- **Increasing Returns**: MP rises, each additional unit of input adds more to the total product.
- **Diminishing Returns**: MP decreases but remains positive, additional units contribute less to the total product.
- **Negative Returns**: MP becomes negative, additional units decrease the total product.

Key Points:
- MP increases until it reaches a peak.
- After the peak, MP decreases, but AP continues to rise until MP equals AP.
- Beyond this point, both AP and MP decline, but total product still increases.
- When MP crosses the x-axis and becomes negative, the total product starts to decrease.

Diminishing Returns
Diminishing returns occur when adding more (labour) of a variable input to a fixed input (capital and land) leads to smaller decreases in output. There are three categories:
1. **Diminishing Total Returns**: The total product decreases with each additional unit of input. This occurs after the point where the total product curve peaks (Point A).
2. **Diminishing Average Returns**: The average product of inputs decreases after the marginal product curve intersects the average product curve.
3. **Diminishing Marginal Returns**: The additional output from each additional unit of input starts to decrease. This begins at the peak of the marginal product curve and continues downward.

Productivity-Improving Technologies
Key Factors:
- **Available Technology**: Converting resources into desired outputs.
- **Organization of Resources**: Effective structuring within firms and industries.

Mechanisms:

- **Adoption of Best Technologies**.
- **Closure of Poorly Performing Firms**.
- **Organizational Changes**: Adjusting structures, management systems, and work arrangements.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/26/0825

MANAGEMENT OF SNAILS IN HORTICULTURAL CROPS

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Snails belong to gastropod family of the Mollusca phylum which has a soft, spiral shell-like body. They are found in moist and marshy areas. They hide under rocks during the day and burrow at night to damage underground tubers like potatoes, leaves and fruit crops. They cause significant damage during the seedling stages of plants and also act as pests and disease vectors. They like damp places and usually feed at night, preferring tender new growth and seedlings. Even though these pests are ground dwellers, they will climb plants and can cause damage well above the ground. Confirming damage by snails can be difficult. However, they can be identified during early morning or late evening, or they can be found glistening slime trails on hard surfaces.

Nature damage

Snails grow in large numbers and cause damage to crops. They especially attack horticultural crops such as potatoes, tomatoes, betel leaves and other crops. They make large holes in the leaves and feed on the contents of the stems, flowers and tubers leading to the death of the plant. The pests eat holes out of leaves creating a tattered appearance. They will crawl into the tightest of spaces to chew away at roots and succulent bulbs. Often the damage can go on for weeks before it is noticed. When temperatures warm in late winter eggs hatch and damage accelerates.

Management methods

- ✓ As the snails and slugs are active during night hours collecting them is a major problem. Sprinkling of coarse materials such as tobacco powder, neem cake, wood flour and groundnut husks on the tops of plants can prevent snails from crawling up.
- ✓ Remove weeds, debris, and decaying organic matter that provide breeding and/or hiding places.
- ✓ Keep shady areas weed and litter-free will reduce their populations.
- ✓ Mix fermented solutions such as yeast, toddy, vinegar solutions with sugar and pour this solution in the earthen plates and place them to the ground level. Snails will be attracted to the solution and fall into it and die.
- ✓ Snails mostly like papaya plants. Papaya powder should be sprinkled near the roots of the plants.
- ✓ Crushed eggshells are an annoyance to slugs. So keep them in orchards.
- ✓ Dust powered salt over the snail wherever it is possible.
- ✓ Place wet gunny bags (approximate: 10/ acre) here and there in the orchards. By keeping them, snails will be attracted and come together. After that, they should be killed by putting them in a bucket of salt solution.
- ✓ The poisonous bait of metaldehyde available in the market, if placed here and there in the field, snails will be attracted and eat them and die.
- ✓ Pour boiled garlic paste water once a week and after rainfall around the tree basins.

- ✓ Spraying the seedlings with Bordeaux mixture (1 kg. Copper sulphate 1 kg. Lime mixed in 100 liters of water) can protect the plants from snails.
- ✓ Keeping copper wires near the roots of newly planted seedlings or young plants will cause them to die due to the electric shock.
- ✓ Spray Mesurol 200 SC @ 0.3 gm. / liter of water in case of sev.re infestation.

Insecticide Bait method
Wheat flour/rice bran - 1 kg
Jaggery - 0.2 kg
Any insecticide - 250 ml

Make jaggery syrup in low heat and mix wheat flour/rice bran along with the insecticide. Make small balls and keep it in 10 places in the field. Wear proper protective gloves while preparing the baits.

Caution : Keep away the poultry and pet animals from the baited field.

Article ID : 05/VIII/27/0825

INVASIVE INSECT PESTS IN AGROECOSYSTEMS: EMERGING THREATS TO CROP SECURITY

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Summary

Invasive insect pests are rapidly becoming one of the biggest threats to global agriculture. These non-native insects—such as the Fall Armyworm, Tomato Leaf miner, and Red Palm Weevil—are spreading rapidly due to climate change, international trade, and monoculture farming. They destroy crops, reduce yields, and cost farmers billions of dollars. India has experienced significant invasions in recent years, impacting maize, tomato, coconut, and coffee plantations. While tools like biological control and digital pest apps offer hope, managing these invaders requires prompt detection, effective policies, and robust awareness among farmers.

Introduction

In the evolving dynamics of global agriculture, a new class of biological invaders is posing unprecedented challenges—**invasive insect pests**. These non-native insects, once limited to localized ecosystems, are now rapidly crossing geographical boundaries, hitchhiking on global trade networks, flourishing under changing climates, and finding ample food in the vast monocultures of modern farming (Nair & Radhakrishnan, 2020). Their growing presence not only disrupts the ecological balance of agroecosystems but also threatens national food security and the economic stability of millions of farming communities. From devastating maize fields in Africa to plundering tomatoes in India, the reach and impact of invasive insect pests are intensifying. They damage crops, overwhelm native biodiversity, reduce yields, increase dependency on chemical pesticides, and place heavy financial burdens on farmers. Understanding their behavior, spread, and management is now a critical priority in securing the future of sustainable agriculture.

Who Are These Invasive Insect Pests?

Invasive insect pests are non-native species that have been introduced—either intentionally or accidentally—into areas where they do not naturally exist. In their new surroundings, these pests frequently encounter a lack of natural predators or diseases, granting them an unchecked advantage. Once they become established, they reproduce swiftly, spread vigorously, and outcompete native species. Their effects can be ecological, economic, and even social.

Recent Invasive Insect Pests and Their Impact: A Global Overview

Pest Name	Origin	Crops Affected	Regions Impacted	Key Impact
Fall Armyworm (*Spodoptera frugiperda*)	Americas	Maize, sorghum, sugarcane, rice	Africa, India, Southeast Asia	Crop losses up to 50%; more than $3 billion loss in African maize (FAO,2022)
Tomato	South	Tomato,	Europe,	Up to 100% yield loss in

Pest Name	Origin	Crops Affected	Regions Impacted	Key Impact
Leafminer (*Tuta absoluta*)	America	potato	Africa, India	tomatoes if unmanaged (CABI, 2023)
Red Palm Weevil (*Rhynchophorus ferrugineus*)	Southeast Asia	Coconut, date palm	Middle East, Europe, India	Causes internal damage; palm death; major concern in Kerala, UAE (EPPO, 2023)
Papaya Mealybug (*Paracoccus marginatus*)	Central America	Papaya, mulberry, cassava	India (Tamil Nadu, Kerala, Assam), Africa	80–90% crop loss in affected areas; controlled with parasitoid wasp (Muniappan *et al*., 2012)
Coffee Berry Borer (*Hypothenemus hampei*)	Central Africa	Coffee	Latin America, Africa, India	Reduces coffee quality and yield; threat to premium coffee export (Kaur & Sohal, 2021)

Why Are Invasive Pests Increasing?

1. **Climate Change**
    - Warmer temperatures allow tropical pests to survive in temperate regions
    - Changes in rainfall, humidity, and wind affect pest reproduction and dispersal
    - Example: Whiteflies now breed year-round in Northern India due to milder winters
2. **Globalization and Trade**
    - Insects are transported in cargo, fruits, plant materials, timber, and ornamental plants
    - Weak port inspections and porous borders increase the risk
    - Example: *Tuta absoluta* likely entered India via tomato imports
3. **Monoculture and Crop Intensification**
    - Vast, genetically uniform fields provide ideal conditions for pest outbreaks
    - Loss of plant diversity reduces natural enemy populations
    - Example: Cotton monocultures led to repeated *Helicoverpa armigera* outbreaks in central India
4. **Lack of Preparedness and Monitoring**
    - Delayed detection and diagnosis lead to uncontrolled spread
    - Insufficient training and infrastructure at the grassroots level

India's Invasive Pest Hotspots (2022–2024)

- **Northeast India**: Rugose Spiraling Whitefly affecting bananas in Assam and Tripura
- **Punjab & Haryana**: Resurgence of Whiteflies in cotton; linked to pesticide resistance
- **Maharashtra**: *Tuta absoluta* and Leaf curl virus complex in tomatoes
- **Sundarbans, West Bengal**: Salinity changes contributing to Brown Planthopper outbreaks in paddy
- **Odisha & Chhattisgarh**: Newly reported *Spodoptera litura* infestations in groundnut and pulses

How Are We Managing These Threats?

- **Biological Control**: Introduction of parasitoids and predators (e.g., *Trichogramma*, *Chrysoperla*)
- **Digital Surveillance Tools**: Apps like Plantix, Pestoz, and FAMEWS are helping with early identification
- **Farmer Training**: KVKs and agricultural universities are spreading awareness on field-based identification and IPM (Kumar & Kalleshwaraswamy, 2019)
- **Legislative Efforts**: The Directorate of Plant Protection, Quarantine & Storage (DPPQS) is enhancing import regulations

Challenges in Invasive Pest Management

- Limited access to real-time pest forecasting at the village level
- Overuse and misuse of chemical pesticides cause resistance
- Weak coordination between researchers, policymakers, and local governments
- Underutilization of traditional pest-resistant landraces and indigenous knowledge

The Way Forward: Building Pest-Resilient Agriculture

1. **Strengthen Phytosanitary Infrastructure**: Invest in customs inspections, diagnostic labs, and border surveillance (Muniappan & Reddy, 2020)
2. **Promote Biological & Ecological Control:** Encourage IPM, polycropping, and agroecological practices
3. **Boost Farmer Engagement**: Train frontline workers, local extension officers, and farmer groups
4. **Enhance Research & Forecasting**: Use AI and remote sensing for early pest detection and rapid response
5. **Regional & Global Cooperation**: Knowledge sharing between pest-affected countries is essential

Conclusion: A Call to Action

Invasive insect pests are not isolated agricultural problems—they are transboundary biological threats capable of destabilizing economies and ecosystems. Their swift spread and destructive potential demand a coordinated, multidisciplinary response rooted in prevention, early detection, and sustainable management. Protecting our agroecosystems from these hidden invaders is no longer an option—it is an urgent necessity. We cannot afford to fight tomorrow's pests with yesterday's tools. Innovation, collaboration, and awareness are the new frontlines in crop protection.

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ISSN : 2583-0910
Agri-India TODAY
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monthly newsletter

Article ID : 05/VIII/28/0825

HARNESSING MODERN BREEDING TECHNOLOGIES FOR CLIMATE-RESILIENT AND NUTRIENT-ENRICHED MAIZE (*Zea mays* L.) IMPROVEMENT

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Abstract

Maize (*Zea mays* L.) is one of the most crucial cereal crops worldwide, playing a vital role in food, feed and industrial sectors. Traditional breeding methods have greatly enhanced maize productivity. However, it often falls short in tackling contemporary challenges like climate change, new pest threats, and evolving nutritional needs. Modern breeding techniques including marker-assisted selection, genomic selection, gene editing, doubled haploid technology and speed breeding provide more precise and efficient approaches to improving maize. This article offers a thorough overview of these advanced breeding tools, how they can be integrated into the plant breeding programs, and their influence on developing resilient, high-yielding and nutritionally enhanced maize varieties.

Introduction

Maize (*Zea mays* L.) is an important crop grown in various agro-climatic zones, providing essential calories and protein for both people and livestock. With global production exceeding 1.2 billion tonnes each year, maize is crucial for food security and economic stability around the world (FAO, 2023). However, modern agriculture is coming into pressure due to rising temperatures, unpredictable rainfall patterns, soil degradation, the emergence of new insect pests and increasing demand of a growing population -all of which are creating an overburden to existing production systems (Shiferaw *et al*., 2011; Tester & Langridge, 2010). Traditional maize breeding methods rely on phenotypic selection and hybridization, which have been essential for boosting yields and enhancing adaptability. However, these methods can be time-consuming, less precise and often inadequate for tackling complex traits such as drought tolerance or nitrogen-use efficiency. In response to these challenges, plant scientists are embracing modern breeding techniques that utilize genetic, genomic and data-driven technologies to accelerate and improve the breeding process.

Plant breeding has undergone remarkable changes in recent decades through the advancements in biotechnology. Traditional methods are effective in enhancing yields and building resistance to various stressors. However, these have some shortfall in terms of speed, precision, and efficiency when it comes to tackling modern agricultural challenges like climate change, increasing population demands and food insecurity. Biotechnology provides a promising solution by facilitating rapid, targeted and efficient crop improvement. Notable breakthroughs such as Next-Generation Sequencing (NGS) and Genomic Selection (GS) enable breeders to delve into plant genomes and predict desirable traits early in the development process. Additionally, CRISPR-Cas9 gene editing has transformed precision breeding by allowing for targeted DNA modifications without the introduction of foreign genes, making it more widely acceptable than conventional

GMOs. Other important tools include Marker-Assisted Selection (MAS), which utilizes DNA markers to choose for specific traits; RNA interference (RNAi), which silences harmful genes to boost pest resistance and nutritional value; and Speed Breeding, which shortens plant growth cycles in controlled environments (Jaganathan *et al.*, 2018). These technologies help in decreasing breeding time and improving crop performance. Transgenic crops (GMOs) such as *Bt* cotton and herbicide-resistant soybeans have led to higher yields and less chemical use, although they face challenges related to regulations and consumers acceptance. New strategies are focused on developing second-generation GMOs that possess complex traits like improved nutrition and climate resilience.

Gene banks and advanced storage technologies are vital for preserving genetic diversity, a key factor in future breeding initiatives. New fields such as synthetic biology and metabolic engineering present thrilling opportunities to develop plants with unique functions, like improved photosynthesis or the capacity to produce biofuels and pharmaceuticals. Moreover, precision agriculture and digital breeding tools—such as artificial intelligence and data analytics—are refining farming practices and accelerating crop development. In the end, blending traditional breeding techniques with cutting-edge biotechnology is transforming agriculture. These innovations are crucial for fostering sustainable food production and enhancing resilience in the face of global challenges.

Modern Biotechnology

Modern biotechnology has transformed plant breeding by providing faster, more precise, and sustainable approaches to developing improved crop varieties that meet the rising demands for food, address climate change and combat global food insecurity. Unlike, traditional breeding methods, biotechnology enables direct manipulation of genes, making it easier to introduce traits such as pest resistance, drought tolerance, and increased yields.

Key Innovations:

1. Genomics & Genomic Selection (GS): Advanced sequencing technologies like Next-Generation Sequencing (NGS) allow breeders to analyze complete genomes and employ genomic selection to forecast plant performance. This method lessens the need for extensive field trials and accelerates the breeding process. It enhances the accuracy of predicting desirable traits of maize such as yield, drought tolerance and disease resistance and also improves the efficiency for complex traits leading to increased productivity and better grain quality.

2. Marker-Assisted Selection (MAS): MAS utilizes molecular markers to identify plants with desirable traits—such as stress tolerance and disease resistance—based on genetic data rather than physical traits. This technique is especially effective for traits governed by single genes and is increasingly being combined with genomic selection to address more complex characteristics. Here it enables the precise observation of beneficial alleles including QTL related to disease resistance or any type of abiotic stress tolerance which shortens breeding time and boosts the chances of developing superior hybrids.

3. CRISPR-Cas9 Gene Editing: CRISPR technology enables precise alterations to specific genes aimed at enhancing crop traits like yield, disease resistance, and stress tolerance without introducing foreign DNA. While it holds great promise for improving food security, it still faces regulatory hurdles and public acceptance challenges. This technique facilitates targeted modification of gene linked to yield, nutritional content and stress response which produces non-transgenic maize line improves traits like lysine content or drought resistance.

4. RNA Interference (RNAi): RNAi works by silencing detrimental genes to produce crops that are both pest-resistant and nutritionally enhanced, thereby extending shelf life. This approach tends to be more readily accepted by the public since it avoids the insertion of foreign genes. It silences specific genes to enhance traits such as pest resistance which results higher yields by reducing biotic stress improving grain quality.

5. Transgenic Crops & Genetic Engineering: Transgenic technology introduces genes from various species into crops to confer new traits, exemplified by Golden Rice (rich in Vitamin A) and *Bt* cotton (which offers insect resistance). Despite notable achievements in this field, concerns regarding GMOs continue to persist. Newer "stacked trait" crops aim to combine multiple beneficial attributes for broader improvements. This will involve incorporated gene from other organism to provide traits like pest resistance or herbicide tolerance and significantly it will boosts productivity, reduces pesticide use and ensures yield stability under biotic stress. In genetic engineering it encompasses broader manipulation of the maize genome to enhance traits such as vitamin content, protein content, or abiotic stress tolerance which results the development of biofortified and climate resilient maize varieties that only offer improved nutritional value and economic advantage.

Recent advances in biotechnology and plant breeding are transforming agriculture, driven by challenges like climate change, food security, and environmental sustainability. Key innovations include gene editing technologies such as CRISPR-Cas9, base editing, and prime editing, which enable precise genetic modifications to enhance crop traits like disease resistance, nutrition, and stress tolerance. These techniques are generally more accepted than traditional GMOs because they modify existing genes without adding foreign DNA. Synthetic biology and metabolic engineering are paving the way for crops with improved photosynthesis, increased resource efficiency, and the ability to produce valuable compounds like biofuels and medicines. There is a growing focus on developing climate-resilient crops capable of withstanding extreme weather conditions, supported by molecular breeding and genomic selection. The integration of digital technologies including AI, machine learning, and big data into biotechnology is speeding up advancements in the field. These tools improve decision-making processes and facilitate high-throughput phenotyping, making it easier to evaluate crop performance across various environments. Collectively, these innovations are shaping a sustainable and productive future for global agriculture.

Conclusion

Modern breeding strategies offer a robust experience for advancing maize improvement in the coming generation. They facilitate the precise, rapid, and data-informed development of resilient, nutritious, and high-yielding maize varieties. Although traditional methods have provided a solid foundation, the future of maize breeding will hinge on the integration of genomics, digital phenotype and biotechnology. It’s essential to address global food insecurity challenges and tackle the impacts of climate change, transitioning to modern science-based breeding systems.

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ISSN : 2583-0910
Agri-India TODAY
visit us at www.agriindiatoday.in
Peer reviewed
monthly newsletter

Article ID : 05/VIII/29/0825

MARKETING ORCHID FLOWERS AND PLANTS : A COMPREHENSIVE OVERVIEW

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Entering the orchid market can be a daunting task for new growers, as orchids follow an unconventional sales path in India. Unlike other flowers, they are not sold in local mandis and instead rely on private arrangements with florists, hotels, restaurants, and event venues. Some growers also connect with exporters or buyers from other states, though this remains difficult for small farmers due to lack of market access and networking. The demand for orchids is largely concentrated in metro cities, with limited appeal in rural regions due to their higher cost.

To bridge the marketing gap, several channels can be utilized. Selling through wholesale flower markets such as Delhi's Ghazipur, Bangalore's KR Market, and Kolkata's Mullick Ghat provides bulk sale opportunities to retailers and decorators. However, organizing growers into clusters for collection and bulk transportation is essential to lower costs and improve market access.

Another common avenue is selling directly to local florists and flower shops, who use orchids for bouquets and floral designs. The growing popularity of online marketplaces such as Amazon and Flipkart, along with specialized flower delivery platforms, offers a promising digital space for growers to reach wider audiences. For those aiming at export markets, collaborating with agents or building capacity to comply with international quality and phytosanitary standards is crucial.

Orchids also hold significant value in the event planning and wedding decoration industries due to their exotic look. Building ties with planners and decorators can ensure steady orders. Similarly, corporate clients use orchids for office decor and gifting, presenting another consistent income stream. Orchids can also be sold through retail outlets like supermarkets and garden centers to tap into broader consumer segments. Subscription services offering regular doorstep delivery of fresh orchids represent an emerging trend in urban markets.

In Kerala, most orchids are sold to major cities like Chennai, Bangalore, Mumbai, and Delhi, with florists playing a key role in value addition through customized floral products. However, such value addition is mostly absent among growers. If equipped with effective marketing strategies, orchid farming in Kerala and similar regions can become a highly profitable agribusiness. There is great potential for new entrants to explore this sector, especially with rising domestic and local demand for potted orchid plants.

One of the major challenges faced by orchid farmers is unorganized marketing, especially for cut flowers. Issues like small production units and lack of proper market infrastructure hinder progress. To address this, experts recommend the establishment of regulated orchid markets, including primary markets in producing regions, city-based wholesale hubs, and export terminals. Reviving dormant producer associations and supporting them through government schemes is also vital.

Urban and Rural Involvement

Urban centers serve as the primary hubs for orchid consumption and trade. City dwellers use orchids extensively for weddings, events, home decor, and gifting. Potted orchids are also popular for interior design and landscaping. Additionally, many urbanites cultivate orchids as a hobby, enhancing their homes and gardens. There's significant potential for urban women, unemployed youth, and aspiring entrepreneurs to take up orchid cultivation as a source of supplementary income. Training programs focused on cultivation techniques, marketing, and business development are essential for empowering these groups. Furthermore, corporate investment in export-oriented orchid farms using greenhouse and tissue culture technologies can enhance both quality and production volume for international markets.

In rural areas, communities traditionally engage in agricultural activities and have a natural aptitude for cultivation. With adequate training and market awareness, they can excel in orchid farming. A collaborative approach involving government bodies, research institutions, banks, and rural organizations is needed for sustainable enterprise development. Marketing success in rural settings depends on consistent demand, reliable production, and strong infrastructure.

A Strategic Marketing Model

The orchid trade has seen significant changes since the COVID-19 pandemic, with an increasing shift toward e-commerce and digital platforms, although traditional outlets like flower shops and supermarkets remain relevant. Future opportunities lie in innovative hybrids and biotech-enabled breeding methods, which can enhance the diversity and appeal of orchid products.

A successful marketing model for orchids in India must include market research, identifying and segmenting potential customer bases such as florists, event planners, retailers, and online shoppers. Product diversification—offering not just cut flowers but also potted plants, gift sets, and value-added items like oils—can broaden appeal. Establishing both direct-to-consumer and wholesale distribution networks ensures wider market reach.

Creating a strong online presence is indispensable. Platforms like Instagram and Pinterest are ideal for visually showcasing orchids and engaging customers. A dedicated website can serve both as a storefront and an educational resource. Meanwhile, brand development—highlighting quality, sustainability, and uniqueness—helps build customer loyalty.

Participation in flower shows and exhibitions allows growers to interact directly with buyers, while collaborations with planners, wedding vendors, and corporates open avenues for bulk sales. Ensuring quality control, acquiring certifications, and actively incorporating customer feedback are key to building trust and long-term success.

Finally, enhancing domestic production capacity, especially in northern India where imports currently dominate, will reduce foreign dependency. Investment in technology and modern practices can equip skilled farmers and entrepreneurs to meet the growing demand, making orchid cultivation a thriving part of India’s floriculture industry.

Role of Government (Central & State):

- **Policy & Regulation:**
    - Establish regulated orchid markets and quality standards.
    - Integrate orchids into national horticulture schemes.

- **Financial Support:**
    - Provide subsidies for greenhouses, irrigation, and tissue culture units.
    - Offer low-interest loans through banks and NABARD.
- **Skill Development:**
    - Organize farmer training and entrepreneurship programs.
    - Promote orchid farming among women, youth, and rural communities.
- **Market Infrastructure:**
    - Create collection clusters, cold chains, and transport systems.
    - Support FPOs and cooperative marketing efforts.
- **Promotion & Export:**
    - Promote orchids in public events and government landscaping.
    - Help growers meet international export standards.

Role of ICAR–NRC For Orchids, Pakyong, Sikkim:

- **Research & Innovation:**
    - Develop high-yielding, disease-resistant orchid varieties.
    - Advance tissue culture and post-harvest technologies.
- **Training & Extension:**
    - Conduct hands-on training for farmers and entrepreneurs.
    - Disseminate best practices in orchid cultivation and marketing.
- **Quality Planting Material:**
    - Produce and supply disease-free, tissue-cultured orchid saplings.
    - Support nurseries and commercial growers with elite varieties.
- **Advisory & Support:**
    - Provide expert advice to growers, state agencies, and exporters.
    - Act as a central hub for orchid-related R&D and outreach.
- **Industry Collaboration:**
    - Promote public-private partnerships for commercial orchid farming.
    - Collaborate with exporters and floriculture businesses.

By working in tandem, the government can provide the infrastructure, policy, and financial backing, while ICAR–NRC Orchids can drive the technical expertise, innovation, and skill development needed for the sustainable growth of the orchid sector in India. This combined approach will help transform orchid cultivation from a niche activity into a profitable, large-scale agri-business enterprise.

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/30/0825

HARNESSING NATURE'S POWER: THE ROLE OF NATURAL PRESERVATIVES IN FISH AND FISHERY PRODUCTS

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Introduction

Fish and fishery products are widely acknowledged for their exceptional nutritional value. They are rich in high-quality proteins, essential fatty acids (like omega-3), vitamins, and minerals, making them a key component of a healthy diet. However, their high moisture content, neutral pH, and presence of non-protein nitrogen make them extremely perishable, leading to rapid spoilage through microbial growth, enzymatic autolysis, and lipid oxidation.

Preservation of fish traditionally relies on chilling, freezing, and chemical additives. However, increasing health concerns and environmental awareness have shifted attention towards safer, natural alternatives. This article explores the rising role of **natural preservatives** especially plant-based phytochemicals, microbial-derived compounds, and animal-based agents in enhancing the safety, shelf life, and sensory qualities of fish and fishery products.

Why Natural Preservatives?

Synthetic preservatives like BHA, BHT, and nitrites have long been used to extend shelf life and prevent spoilage. However, these chemicals have been linked to health risks such as liver toxicity, hormonal disruption, and even carcinogenic effects. In contrast, natural preservatives are often considered safe (GRAS - Generally Recognized as Safe), biodegradable, and eco-friendly. Their acceptance by both industry and consumers is steadily growing.

Mechanisms of Spoilage in Fish

1. **Microbial Spoilage:** Bacteria such as *Shewanella*, *Pseudomonas*, and *Photobacterium* metabolize fish components to produce off-flavors, slime, and hazardous compounds like trimethylamine (TMA) and biogenic amines.
2. **Lipid Oxidation:** Unsaturated fats in fish are prone to oxidation, especially under exposure to air, light, and temperature. This leads to rancidity, flavor loss, and nutritional degradation.
3. **Autolysis:** Endogenous enzymes like cathepsins and trypsins break down proteins after death, weakening muscle structure and promoting spoilage.

Natural Preservatives: Sources, Applications, Advantages & Disadvantages

Natural preservatives for fish and fishery products are derived primarily from plants, microorganisms, and animal-based compounds. Their roles include inhibiting microbial growth, reducing lipid oxidation, and preserving texture and flavor. While these are generally safer and more sustainable alternatives to synthetic additives, they also come with limitations.

1. Plant-Derived Preservatives : Natural preservatives from herbs, spices (like rosemary, clove, turmeric), fruit and vegetable peels (grape skin, citrus peel), and seaweeds (*Ulva*, *Gracilaria*) are rich in polyphenols, flavonoids, essential oils, and terpenoids. They are used in marinades, edible films, or added to ice for chilled storage. These compounds offer antioxidant and antimicrobial benefits, are biodegradable, GRAS-certified, and even help in utilizing agro-wastes. However, they can have strong flavors that may alter product taste, show compositional variation due to plant source and season, have limited heat stability, and may face regulatory hurdles.

2. Microbial-Derived Preservatives : Lactic acid bacteria, yeasts, and fungi produce natural antimicrobials like bacteriocins (e.g., nisin), organic acids (lactic, propionic), and hydrogen peroxide. They are commonly used in fermented fish, vacuum-packaged products, or alongside cold storage. These agents are generally odorless, effective against specific spoilage microbes, cost-efficient (especially when produced in situ), and fit well into clean-label trends. However, their antimicrobial spectrum may be limited, they often require precise pH or refrigeration, and scaling up production or meeting regulatory approval can be complex.

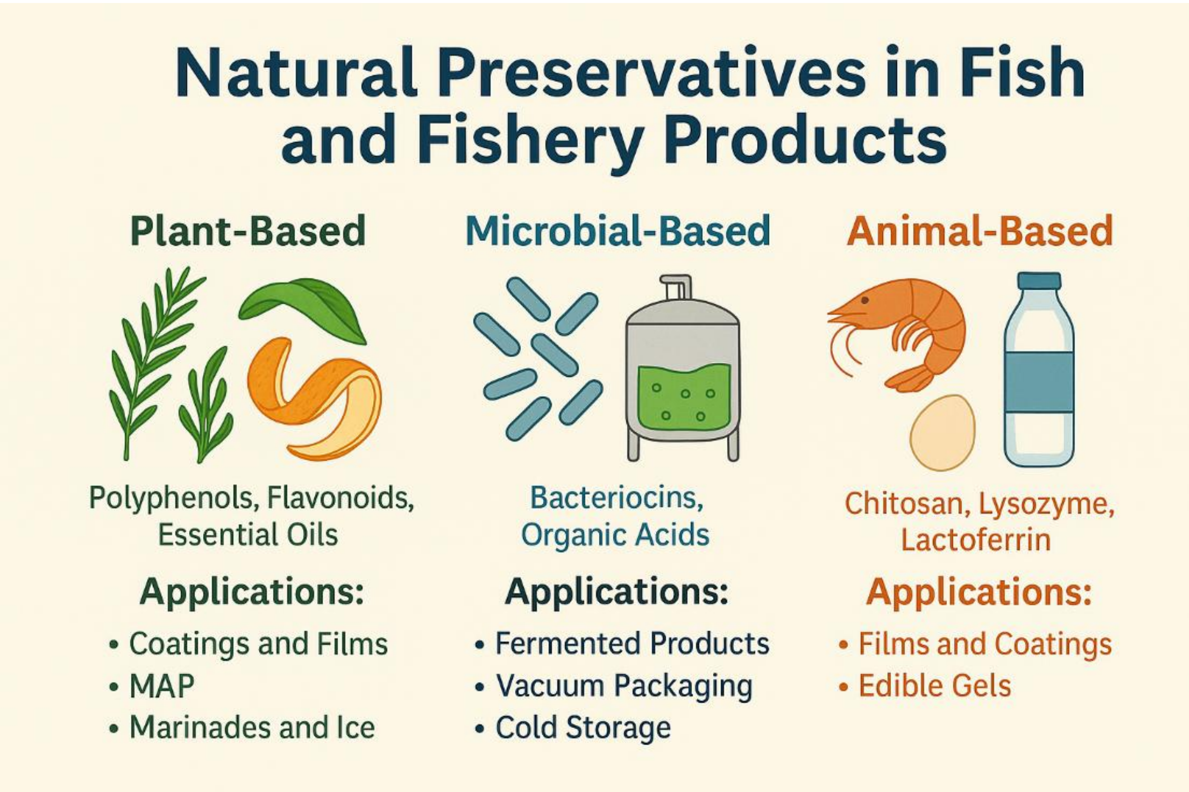

Figure 1. Overview of natural preservatives in fish and fishery products, categorized by source plant-based, microbial-based, and animal-based with key bioactive compounds and their common applications.

3. Animal-Derived Preservatives : Derived from chitosan (shellfish), lysozyme (egg), and lactoferrin (milk), these compounds are used in antimicrobial coatings, edible films, or packaging with essential oils. They have excellent film-forming and antimicrobial properties and can improve shelf life without major sensory changes. Nevertheless, concerns include allergenicity, ethical/dietary restrictions (e.g., vegan or halal compliance), relatively high cost, and limited consumer acceptance in some regions.

Table 1. Comparison of Natural Preservatives from Plant, Microbial, and Animal Sources: Key Compounds, Benefits, and Limitations in Fish and Fishery Product Applications.

Source	Key Compounds	Main Benefits	Limitations
Plants	Polyphenols, EOs	Safe, eco-friendly, antioxidant-rich	Strong flavor, variability
Microbes	Bacteriocins, acids	Targeted antimicrobial effect	Spectrum limitations, scale-up
Animals	Chitosan, lysozyme	Film-forming, broad-spectrum action	Allergen risk, dietary limitations

Natural Preservative Technologies and Challenges

To improve the effectiveness and stability of natural preservatives in fish and fishery products, several advanced technologies have been developed. **Encapsulation techniques** protect sensitive compounds like essential oils and polyphenols from degradation while enabling slow release and improved solubility—helpful in applications such as nanoencapsulated clove oil for shrimp preservation. **Edible coatings and films**, made from proteins or polysaccharides and infused with natural extracts (e.g., green tea or thyme oil), form a protective barrier against microbes and moisture, enhancing shelf life while being biodegradable**. Active packaging systems** integrate antimicrobial agents directly into packaging materials to offer continuous protection without direct contact, often used with extracts like oregano or grape seed oil. **Hurdle technology**, which combines methods like low-temperature storage, MAP, or UV light with natural preservatives, offers synergistic effects for microbial control while preserving sensory quality. Additionally, **cold plasma treatment** with natural agents provides non-thermal microbial decontamination, and **ice supplementation** using plant or seaweed extracts delivers continuous preservative action during chilled storage—simple yet effective for small-scale operations.

Despite these innovations, some challenges hinder widespread adoption. Natural extracts can vary in quality depending on the source and extraction methods, leading to inconsistent results. Their strong aroma or color may affect the sensory qualities of fish, and some may degrade more quickly than synthetic counterparts. Regulatory differences across regions, high production costs, limited compatibility with existing preservation processes, and narrow antimicrobial spectra further complicate implementation. Additionally, consumer misconceptions about natural preservatives and potential allergens (like chitosan from shellfish) require clear labeling and education.

To overcome these limitations, coordinated efforts are needed in research, regulatory harmonization, process optimization, and consumer outreach. By developing stable, standardized formulations and integrating them with existing cold chain and packaging systems, the fish processing industry can better utilize natural preservatives while aligning with growing demand for clean-label and sustainable products.

Conclusion and Future Prospects

Natural preservatives offer a promising, sustainable solution for enhancing the safety and shelf life of fish and fishery products. Their dual role as antioxidants and antimicrobials, combined with consumer preference for "green" and clean-label foods, positions them as key players in modern fish preservation.

Going forward, research into synergistic blends, smart delivery systems, and novel sources like marine algae and fungi will likely broaden their application. Collaboration between scientists, food technologists, and regulatory bodies will be essential to scale up and commercialize these natural solutions effectively.

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Article ID : 05/VIII/31/0825

PHYTOPARASITIC NEMATODE MANAGEMENT IN HIGH-VALUE SPICE AND AROMATIC CROPS

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Abstract
Spice and aromatic crops are highly susceptible to phytoparasitic nematodes, which hinder plant growth and reduce yield. Integrated Nematode Management (INM) offers a sustainable solution through a combination of cultural, biological, chemical, and genetic strategies. Practices like using nematode-free planting material, crop rotation, soil solarization, organic amendments, biocontrol agents, and resistant varieties effectively reduce nematode populations. This holistic approach ensures healthier crops, improved soil fertility, and reduced chemical dependence, making INM essential for the long-term productivity and sustainability of spice and aromatic crop cultivation.

Keywords: Phytoparasitic nematodes, spice crops, biocontrol agents, resistant varieties, sustainable.

Introduction

Spice and aromatic crops, renowned for their culinary, medicinal, and industrial importance, are increasingly vulnerable to infestation by phytoparasitic nematodes microscopic, soil-dwelling roundworms that invade root tissues and disrupt vital physiological functions. These pests impair water and nutrient uptake, leading to chlorosis, stunted growth, wilting, reduced yield, and, in severe cases, plant death. Crops such as black pepper (*Piper nigrum*), ginger (*Zingiber officinale*), turmeric (*Curcuma longa*), cardamom (*Elettaria cardamomum*), davana (*Artemisia pallens*), mint (*Mentha spp*.) and patchouli (*Pogostemon cablin*) are notably susceptible. Among the most destructive nematode species are root-knot nematodes (*Meloidogyne* spp.), burrowing nematodes (*Radopholus similis*), and lesion nematodes (*Pratylenchus penetrans*), which can persist in diverse soil environments and cause c hronic damage if left unmanaged. Effective control demands an integrated approach tailored to the crop and nematode species, combining preventive sanitation measures, cultural practices like crop rotation and organic amendments, biological agents such as *Purpureocillium lilacinum* and *Pochonia chlamydosporia*, and judicious use of eco-safe chemical nematicides. Emphasis on integrated nematode management is crucial for safeguarding plant health, improving productivity and ensuring long-term viability of these high-value crops.

Integrated Nematode Management (INM)

Integrated Nematode Management (INM) is a holistic approach that combines multiple strategies to control nematode populations while minimizing environmental impact and promoting sustainable agriculture. By integrating cultural, biological, chemical, and resistant variety-based methods, INM reduces reliance on any single approach, enhances long-term soil health, and ensures crop productivity. Below are the key components of INM for managing nematodes in spice and aromatic crops:

Cultural Practices:

- **Nematode-free Planting Material**: Using clean, certified planting material (e.g., seeds, rhizomes, or cuttings) is critical to prevent introducing nematodes into fields or nurseries. Inspect and source materials from reputable suppliers to avoid infestations.
- **Rabbing**: Involves **burning trash, crop residues, or weeds on the soil surface**, where the resulting heat kills nematodes, weed seeds, and soil-borne pathogens in the top layer, while the ash enriches the soil with nutrients like potash.
- **Crop Rotation**: Rotating spice and aromatic crops with non-host crops like rice, maize, or legumes (e.g., *Mucuna purita*) disrupts the nematode life cycle, reducing population buildup in the soil.
- **Soil Solarization**: Covering moist soil with transparent plastic sheets for 40–60 days during hot seasons traps solar heat, killing nematodes and other soilborne pests. This is particularly effective for nursery beds in ginger and turmeric.
- **Fallowing**: Leaving fields fallow, especially during summer, starves nematodes by removing host plants, significantly lowering their populations before replanting.
- **Mulching**: Applying organic mulches like Guatemala grass (*Imperata cylindrica*) in black pepper suppresses nematode activity, improves soil health, and retains moisture.

Biological Controls:

- **Biocontrol Agents**: Beneficial microorganisms like *Trichoderma harzianum*, *Pochonia chlamydosporia*, *Paecilomyces lilacinus*, *Bacillus firmus, Pasteuria penetrans* and *Glomus mosseae* attack nematodes or their eggs, reducing populations naturally. For example *Pochonia chlamydosporia* applied to ginger and turmeric at 50 g/m^3 row effectively controls root-knot nematodes.
- **Organic Amendments**: Adding neem cake, Pongamia (karanja) cake, mustard cake or distillation waste (e.g., from curry leaf, palmarosa or lemongrass) to soil enriches it with compounds toxic to nematodes, enhancing soil microbial activity and suppressing pest populations.
- **Trap Crops**: Planting marigold (*Tagetes* spp.) as a trap crop lures root-knot nematode away from main crops like black pepper, where they fail to reproduce, reducing overall populations.

Chemical Controls:

- **Targeted Nematicides**: Novel nematicides like Fluopyram 400 SC (34.48% w/w) @ 625 ml/lit. Chemicals like Carbofuran, Phorate, Fenamiphos, Ethoprophos and Oxamyl are effective against nematodes when applied at recommended rates and times. For example, carbofuran 3G at 4 kg a.i./ha in cardamom nurseries or 11 kg/ha in ginger fields controls root-knot and burrowing nematodes, respectively.

- **Application Timing**: Timing is crucial to maximize efficacy and minimize environmental impact. Applications are typically scheduled post-germination, during transplanting, or at specific intervals
- **Safety Considerations**: Follow local regulations and safety guidelines when using nematicides to protect workers, consumers, and the environment.

Resistant Varieties:

- Planting nematode-resistant or tolerant crop varieties reduces the need for chemical interventions. For Balck Pepper varities like Pornami, mint varieties like Kosi and Kalka (menthol mint), Kiran (bergamot mint) and Neer-Kalka (spearmint) show resistance to lesion and root-knot nematodes. Similarly, Kukrail (peppermint) and Arka Neera (spearmint) are less susceptible to root-knot nematodes.
- Grafting susceptible crops like patchouli onto resistant rootstocks (e.g., wild patchouli) can enhance tolerance to root-knot nematodes.

Integrated Approaches:

- Combining multiple strategies amplifies control. For example, in black pepper, integrating neem cake application with *Paecilomyces lilacinus* and *Pasteuria penetrans* provides robust control of root-knot nematodes. Similarly, combining crop rotation with rice-potato or maize-potato and applying *Trichoderma harzianum* in mint fields enhances long-term nematode suppression.
- Regular monitoring of fields for nematode symptoms (e.g., galls, lesions, or stunted growth) allows early intervention, preventing widespread damage.

By adopting INM, farmers can create a balanced, sustainable system that not only controls nematodes but also improves soil fertility, reduces chemical dependency, and supports long- term crop health.

Conclusion

Nematodes pose a significant threat to spice and aromatic crops, but with proactive management, their impact can be minimized. By combining nematode-free planting material, soil treatments, resistant varieties, and biological controls, farmers can protect crops like cardamom, ginger, turmeric, davana, mint, and patchouli from yield losses. Sustainable practices, such as crop rotation, mulching, and biocontrol agents, not only reduce nematode populations but also promote long-term soil health. Implementing these strategies ensures healthier crops, higher yields, and sustainable farming practices for these valuable spice and aromatic crops.

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Table: 1. Integrated Nematode Management of Spice and Aromatic crops

Spice Crops			
Crop	**Nematode**	**Symptoms**	**Management Strategies**
Black Pepper (*Piper nigrum*)	Burrowing nematode (*Radopholus similis*)	▪ Yellowing and leaf shedding ▪ Halted growth, die-back, spike shedding • Orange to purple lesions on thin roots	• Use nematode-free planting material • Solarize nursery sites/potting mix • Mulch with Guatemala grass • Uproot affected vines, replant after 9–12 months • Use non-living supports
	Root-knot nematode (*Meloidogyne incognita*)	• Poor growth, yellowing leaves • Heavy root galling	• Avoid susceptible intercrops (e.g., banana, ginger, turmeric) • Apply neem cake (200 g/vine) • Grow marigold as a trap crop • Apply carbofuran/phorate at 3 g a.i./vine in May–June and Sept–Oct Grow *Siratro* as a cover crop • Use *Paecilomyces lilacinus* and *Pasteuria penetrans*
Cardamom (*Ammomum subulatum*)	Root-knot nematode (*Meloidogyne incognita*)	• Yellowing and drying of leaf tips/margins • Stunted growth and poor vigor • Premature shedding of capsules • Heavy root galling and abnormal branching	• Apply carbofuran 3G at 4 kg a.i./ha in nurseries 10 days after germination, repeat every 3 months • Treat secondary nurseries with carbofuran at 4 kg a.i./ha post-transplanting, repeat every 3 months • Use nematode-free planting material
Ginger (*Zingiber officinale*)	Root-knot nematode (*Meloidogyne incognita*)	• Stunted plants with yellowing leaves • Small root galls	• Use nematode-free seed rhizomes • Solarize nursery beds for 40 days • Treat rhizomes with hot water (50°C, 10 min) • Apply *Pochonia chlamydosporia* on sorghum seeds at 50 g/3 m row

	Burrowing nematode (*Radopholus similis*)	• Stunted growth, reduced tillering • Chlorotic top leaves with scorched tips • Dark lesions on rhizomes	• Select nematode-free rhizomes, treat with hot water (40°C, 20 min) • Apply carbofuran 3G at 11 kg/ha in mid- November and mid-January
Turmeric (*Curcuma longa*)	Root-knot nematode (*Meloidogyne arenaria*)	• Stunted plants with yellowing leaves • Small root galls	• Apply *Pochonia chlamydosporia* on sorghum seeds at 50 g/3 m row • Practice fallowing and treat soil with carbofuran • Use clean planting material
Aromatic Crops			
Davana (*Artemisia pallens*)	Root-knot nematode (*Meloidogyne incognita*)	• Chlorotic, stunted plants with patchy growth • Fewer flowers, severely galled roots	• Apply neem cake at 2 t/ha • Use distillation waste (curry leaf, palmarosa, lemongrass, or vermicompost from pyrethrum, marigold, menthol mint) • Apply *Trichoderma harzianum*
Mint (*Mentha* spp.)	Lesion nematode (*Pratylenchus penetrans*)	• Stunted plants, reduced root/sucker growth • Wilting, chlorosis - Brown to black lesions on suckers/roots, cortical rot	• Apply neem/mustard cakes at 1.5 t/ha • Use Fenamiphos (5.6 kg/ha), ethoprophos (6 kg/ha), or oxamyl (1 kg/ha) • Grow resistant varieties (Kosi, Kalka for menthol mint; Kiran for bergamot mint; Neer-Kalka for spearmint)
	Root-knot nematode (*Meloidogyne incognita*)	• Small to medium root galls • Stunted, poorly tillered plants with chlorotic leaves • Reduced yield	• Apply *Glomus mosseae* or neem cake (5 t/ha), or carbofuran (3 kg a.i./ha) • Rotate with rice-potato or maize-potato • Integrate neem cake with *Trichoderma harzianum* • Grow resistant varieties (Kukrail for peppermint; Arka Neera, Neer-Kalka for spearmint; *Kiran* for bergamot mint)

Patchouli (*Pogostemon patchouli*)	Root-knot nematode (*Meloidogyne incognita*)	• Weak, slow-growing plants • Heavy root galling • Stunting, wilting, chlorosis, defoliation	• Rotate with *Mucuna purita* • Practice summer fallowing • Apply carbofuran (2 kg a.i./ha), neem cake (4 t/ha), *Glomus fasciculatum* (50 kg/ha), or *Trichoderma harzianum* • Graft cultivated patchouli scions onto wild patchouli rootstock

Article ID : 05/VIII/32/0825

EMERGING POSTHARVEST TECHNOLOGIES TO ENHANCE THE SHELF-LIFE OF FRUIT AND VEGETABLES

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Introduction

Improving security, advancing environmental sustainability, and cutting production costs all depend on minimizing losses and waste in the production of fruits and vegetables. Optimal postharvest handling can minimize microbial growth and contamination, reduce or inhibit the development of physiological disorders, and slow down biological processes caused by senescence and maturation. This includes managing storage time and temperature, relative humidity, chemical and/or physical treatments, and packaging (i.e., a modified atmosphere) (Mahajan *et al.,* 2014). The traditional techniques for assessing the quality of fruits and vegetables—sensory assessments and analytical methodologies—are costly, time-consuming, damaging, and labor-intensive. Furthermore, these methods are not appropriate for in-line use in commercial or industrial settings to provide consumers with real-time information about the quality of the product in question. Conversely, new contactless and non-destructive technologies such as electronic noses, hyperspectral or multispectral imaging, image analysis, and near-infrared spectroscopy offer many benefits over traditional destructive techniques for fresh produce quality monitoring (Chauhan *et al.,* 2017).

Postharvest Strategies to Extend the Shelf-Life of Fruit and Vegetables

Microwave

The purpose of the microwave was to quickly and efficiently raise the temperature without creating a temperature gradient. According to (Usall *et al.,* 2016), this method quickly treats fruits and vegetables to control microbial development during the minimal processing of the product, limiting quality losses while also ensuring the least amount of environmental impact and the absence of residues in the treated product. However, a microwave treatment that is too long or too intense might cause an excessive rise in temperature, which can harm new tissue because of uneven heating (Vadivambal *et al.,* 2010). To successfully use a microwave procedure on an industrial scale for fresh and minimally treated food, a number of obstacles must be addressed.

Pulsed Electric Field

This method has been applied extensively to liquid, semi-solid, and solid dishes, as well as to juices and smoothies made with fresh fruit and vegetables. The intensity of the electric fields, the duration of treatment, and the frequency, polarity, or form of the pulses are the PEF parameters that must be regulated to achieve microbiological and enzymatic inactivation in fresh items. The use of PEF in fresh-cut products is restricted, though, as PEF-induced metabolic stress may have a detrimental effect on the finished product's quality. PEF treatment reduced the browning index and acrylamide level in ready-to-eat lotus root during postharvest life, according to one of the few studies examining the effects on the metabolism and traits of minimally processed produce (Li *et al.,* 2020).

High Hydrostatic Pressure

The primary applications of high hydrostatic pressure (HHP) technology are enzyme denaturation and microbial inactivation or reduction. High pressure, which damages microbial cellular structures, may have comparable effects on plant cells; hence, a thorough investigation into treatment optimization in a variety of novel systems is necessary. Numerous findings indicate that HHP has a major impact on microbial burden; nevertheless, because of the large range of product types, it also specifically and variably impacts the functionality of proteins, including enzymes and tissue structure (Rux *et al.,* 2020).

Cold Plasma

In the entire and minimally processed fruit and vegetable industry, cold plasma is widely used as a cutting-edge technology to manage microbial development (Bagheri *et al.,* 2020). The goal is to replace traditional sanitation treatments while maintaining the antioxidant and nutritional qualities of food products. Plasma therapy has been applied to a number of fruit-based fresh-cut goods with positive results in terms of quality metrics and microbiological growth inhibition. The use of plasma-activated water (PAW) has also been the subject of increased research in recent years. This method is a useful substitute for the traditional option of washing during fresh-cut processing for a number of goods since it enables the manufacturer to prevent cell damage brought on by direct exposure to cold plasma.

Dipping and Vacuum Impregnation

The process of dipping involves immersing the product—either mechanically or by hand—and then draining the excess solution. Because it promotes solution dispersion and covers the product's maximal surface area without causing damage or stress, this approach is frequently employed on whole, peeled, shredded, and sliced commodities as well as more perishable products (Martín-Diana *et al.,* 2007). The elimination of cellular exudates, which can negatively impact the postharvest quality of commodities, is one of the main benefits of these dipping procedures. The dipping process's factors that need to be optimized, depending on the food product, include the temperature, solute composition, frequency, soaking time, and solution concentration.

Conclusion

A biocontrol approach and physical treatments (such cold plasma, high hydrostatic pressure, pulsed electric fields, and microwaves) were effective in increasing product safety and, as a result, shelf life. When producers want to maintain the freshness and improve the nutritional content of fresh fruits and vegetables, they should use technologies like dipping, vacuum impregnation, and edible active packaging. Furthermore, combining additional methods from those that have been documented could improve the items' quality and safety. Thus, in order to meet the demands of consumers, the fruit and vegetable industry has innovated by implementing these technologies. Cost analysis is required to confirm the true applicability, though.

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ISSN : 2583-0910
Agri-India TODAY
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Article ID : 05/VIII/33/0825

ORGANIC FARMING MARKETS: TRENDS AND ECONOMIC ANALYSIS

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Abstract

The economy's growth, particularly in developing nations, depends heavily on the performance of the agricultural sector. The economy benefits from it in a number of ways, including higher farmer incomes, jobs in rural areas, and—above all—food security. To boost output in response to the rising demand for food, farmers apply a lot of pesticides and fertilizers. This over use of fertilizers destroys plants and animals, pollutes rivers, lowers soil fertility, and is connected to a number of illnesses in humans. Conventional farming thus presents a number of environmental and health-related issues. Because of some of the drawbacks of traditional farming, organic farming has grown in popularity. Organic agricultural methods are evolving in our nation.

Key words : Organic Farming; Farmers; Agriculture; Production; Environment; India

Introduction

India's diverse range of agroclimatic zones, long history of agriculture, and people's deep connections to the land make it an interesting place to study the dynamics of organic farming. This article attempts to do an economic analysis based on the most recent research findings and interpret the present trends impacting the Indian organic farming industry. Nedumaran *et al.* (2020) found that over the past 10 years, organic farming techniques have gained more and more attention as a potential solution to the issues facing the agriculture industry. Organic farming has promise for enhancing food quality, conserving nonrenewable resources, and safeguarding the environment. It stated that from both the consumer and farmer perspectives, organic farming is necessary for society. Organic farming has the potential to be the answer for transforming rural agriculture into a highly sustainable industry. It can serve as a foundation for sustainable agriculture, cover conversion costs, and preserve soil sustainability.

Agricultural development strategy in India and its impact

Since India gained its independence, the agricultural sector has played a crucial role in determining the course of the nation's growth. Following independence, the Indian economy was heavily reliant on agriculture, with 72% of the labor force and 50% of the country's GDP coming from this sector (Tripathi & Prasad, 2009). Four stages can be distinguished in the development of Indian agriculture, according to these two authors. The government implemented the required land reforms to support agriculture in the initial period following independence.

The second phase began following the severe drought in the middle of the 1960s. In the late 1960s, India embraced the new green revolution approach, which helped the country achieve food grain self-sufficiency. A focus on milk, fisheries, poultry, vegetables, and fruits characterized the following phase of the agriculture sector's diversification. Phase four examined the effects of the 1991 changes on agriculture; however, no reforms were put into effect right once (Tripathi & Prasad, 2009). Indirect effects on this sector were caused by the devaluation of the currency, the opening of international trade, and the elimination of industry protection. In addition to supporting the domestic food needs of 1.35 billion people in 2020–21, it supports global trade and industrial development. At present prices, the agriculture sector contributed 20% and 9.2%, respectively, to gross value added (GVA)1 and gross capital formation (GFC)2 in 2020–21 (Table 1).

Table 1: GVA and GCF of Agriculture, Forestry & Fishing at Current Prices		
Year	Gross Value Added (GVA)	Gross Capital Formation (GCF)[3]
2011-12	18.5	8.5
2012-13	18.2	7.7
2013-14	18.6	9.0
2014-15	18.2	8.2
2015-16	17.7	7.1
2016-17	18.0	7.8
2017-18	18.3	7.2
2018-19	17.6	7.0
2019-20	18.3	7.3
2020-21	20.0	9.2

(Source: - Agriculture Statistics at a Glance, 2021)

An overview of organic farming on a global and Indian scale

1. **Statistics on the global organic farming market:**

The global organic farming market is booming, with impressive statistics demonstrating its rapid growth and significant potential. Here are some key figures to paint a picture:

A. **Market size:**

- The market is expected to grow at a compound annual growth rate (CAGR) of 11.60% over the next ten years, from its estimated valuation of USD 183.35 billion in 2023 to USD 546.97 billion by 2032 (Organic Farming Global Market Report 2024).
- This robust rise is indicative of rising consumer desire for sustainable, healthful food options as well as growing consciousness of the environmental benefits of organic farming.

B. **Product segments:**

- **Fruits and vegetables:** In 2022, this market category held a 42 percent global share, making it the dominant one (Precedence Research, "Organic Food Market Size, Trends, Share, Growth, Report 2032).
- **Meat, fish, and poultry:** This market category is expanding significantly and had a 21% market share in 2022 despite difficulties in organic production (Precedence Research, "Organic Food Market Size, Trends, Share, Growth, Report 2032).

2. **Major contributing states:**

According to the Agricultural and Processed Food Products Export Development Authority (APEDA), Madhya Pradesh leads the way in organic farming, with about 613,000 hectares under such procedures. With 569,000 hectares, Rajasthan comes in second place and makes a substantial contribution to the organic farming scene. According to APEDA data, Maharashtra is the third-largest state with 422,000 hectares planted to organic farming. Notable states in the field of organic farming include Andhra Pradesh, Karnataka, and Tamil Nadu. Sikkim stands out as a state that practices 100% organic farming. This geographical analysis demonstrates these states' significant influence and range of contributions to the organic agriculture industry.

3. Major organic crops:

Fruits and vegetables, including mangoes, bananas, apples, grapes, onions, potatoes, and leafy greens, are the most popular crops in the organic agricultural industry. Consumer preferences are dominated by these fresh produce products, which reflects an increasing trend toward more ecologically friendly and healthful options. Along with fruits and vegetables, pulses are becoming increasingly popular in the organic industry due to their high nutritional content and rising demand, particularly for organic lentils, chickpeas, and pigeon peas. Organic turmeric, ginger, chillies, and black pepper are in high demand due to their alleged health advantages, and the market for organic spices is expanding.

Zone wise organic production (cultivated plus in conversion)

Six zones—Northern, Southern, Eastern, North-Eastern, Western, and Central—were created to analyze the production of organic farming in each of the Indian states (cultivated plus in-conversion) (Heena *et al.,* 2021a). The northern region included Punjab, Uttar Pradesh, Uttarakhand, Jammu & Kashmir, Himachal Pradesh, and Haryana. Arunachal Pradesh, Assam, Manipur, Nagaland, Tripura, Sikkim, and Meghalaya are all part of the northeastern seven zones. West Bengal, Odisha, Jharkhand, and Bihar make up the Eastern zone. Rajasthan, Maharashtra, Goa, and Gujarat are all part of the Western zone. Kerala, Andhra Pradesh, Telangana, Tamil Nadu, and Karnataka make up the southern zone. The Central zone consists of Chhattisgarh and Madhya Pradesh.

Challenges of organic farming

- Organic farming involves more labor intensive practices, the use of specialized knowledge, and investments in organic inputs such as compost and natural pest control solutions.
- Organic farms may experience lower yields due to the reliance on natural methods for pest control and soil fertility management.
- Organic farmers avoid the use of synthetic pesticides and fertilizers, relying on crop rotation, cover cropping, and organic amendments. While these methods promote long-term soil health, they may be less immediately effective than their conventional counterparts.
- The distribution channels and infrastructure for organic products are often less developed compared to conventional agriculture. Organic farmers may face challenges in reaching consumers efficiently, with fewer available market outlets and logistical support.
- Conventional agriculture enjoys economies of scale and established market channels, allowing for mass production and distribution at lower costs. This poses a competitive challenge for organic producers, who may find it challenging to match the efficiency and pricing of conventional farming operations.

Opportunities of organic farming

- The increasing awareness among consumers about health, environmental sustainability, and ethical sourcing has led to a growing demand for organic products. This trend creates significant market opportunities for farmers and businesses engaged in organic farming.

- Many governments around the world recognize the benefits of organic farming and offer support in various forms. This support may include financial incentives, subsidies, technical assistance, and market development programs.
- Ongoing innovations in organic farming practices, such as the development of biofertilizers, precision agriculture technologies, and other sustainable farming techniques, contribute to improving yields, reducing production costs, and enhancing overall sustainability.
- Beyond traditional organic crops, there is an opportunity for farmers to diversify into value-added products, such as organic processed foods, cosmetics, and textiles. This diversification not only expands the range of organic offerings but also creates new market opportunities and revenue streams.
- Leveraging direct-to-consumer channels, including online platforms and farmers' markets, allows organic farmers to establish a direct connection with consumers. This approach enables farmers to command higher prices for their products, reduces dependence on intermediaries, and fosters a sense of trust and transparency with consumers.

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ISSN : 2583-0910
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Article ID : 05/VIII/34/0825

PATENT ISSUES AND SEED MONOPOLIES IN INDIA

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Abstract
Patent issues and seed monopolies in India present complex challenges at the intersection of intellectual property rights and agricultural sustainability. While Indian patent law excludes plants and seeds from patentability under Section 3(j) of the Patents Act, recent judicial interpretations and biotechnology advances have blurred these boundaries, allowing process patents related to genetic modification. This has facilitated multinational corporations' control over seed markets through patent-protected genetically modified (GM) seeds and hybrids, restricting farmers' traditional practices such as seed saving. The Protection of Plant Varieties and Farmers' Rights (PPVFR) Act offers some safeguards but faces enforcement challenges. Ongoing legal disputes and policy debates highlight the tension between fostering innovation and protecting farmers' rights, biodiversity, and food security. Parliamentary committees have recommended revisiting patentability norms with government participation and stakeholder consultations to balance these competing interests.

Keywords: Farmers' rights, GM seeds, Patent law, and Seed monopoly

Introduction
India's agricultural sector is undergoing a transformation driven by biotechnology and intellectual property (IP) regimes that increasingly influence seed production and distribution. The core issue revolves around the patentability of plants and seeds, which directly impacts seed monopolies and farmers' autonomy. Indian patent law traditionally excludes plants and seeds from patent protection to safeguard farmers' rights and biodiversity. However, the rise of genetically modified organisms (GMOs) and process patents for genetic engineering has enabled private companies to assert control over seeds. This has sparked legal conflicts and policy debates about balancing innovation incentives with the preservation of traditional farming practices and food security.

Legal framework governing seeds and patents in India
India's Patents Act, 1970, amended in 2005 to comply with TRIPS, explicitly excludes patenting of plants and seeds under Section 3(j), which bars "essentially biological processes" for plant propagation. However, patent protection is available for biotechnological processes involving human intervention, such as genetic modification and hybrid seed development, as clarified by the landmark Sakata Seed case. This case established that patents could be granted for technical innovations involving plants if they involve significant human intervention beyond natural biological processes.

The Protection of Plant Varieties and Farmers' Rights (PPVFR) Act, 2001, complements patent law by protecting plant breeders' rights and recognizing farmers' rights to save, use, exchange, and sell farm-saved seeds. Despite this, enforcement issues and overlapping jurisdictions sometimes weaken the protection of farmers against corporate monopolies.

Seed Monopolies and corporate

Control Multinational corporations, including Bayer-Monsanto and Advanta, have leveraged process patents and plant variety registrations to dominate seed markets, especially for hybrid and genetically modified crops like cotton and maize. Legal disputes, such as the 2025 Advanta vs. Yaganti case, demonstrate courts' willingness to enforce breeders' rights and restrain unauthorized seed sales, reinforcing corporate control.

The monopolistic control over seeds restricts farmers' traditional practices of saving and exchanging seeds, increases dependency on expensive patented seeds, and raises input costs. This scenario threatens agricultural biodiversity and farmers' livelihoods, especially smallholders.

Policy Debates and parliamentary recommendations

The Department-Related Parliamentary Standing Committee on Intellectual Property Rights recommended revisiting the patentability of plants and seeds, suggesting the government become a participant in patent rights to protect national interests. The committee advocates for extensive consultations with farmers and stakeholders before allowing patents on plants and seeds, emphasizing safeguards to protect farmers' rights and biodiversity.

Parallelly, the Seeds Bill (2019) aims to regulate the quality of all seeds sold in India, including hybrids and private-sector varieties, ensuring transparency and accountability in seed performance and quality standards.

Socioeconomic and Environmental implications

Seed monopolies driven by patent protections exacerbate socioeconomic inequalities, as smallholder farmers face increased costs and reduced seed sovereignty. Loss of seed diversity due to corporate dominance threatens ecological resilience and sustainable agriculture. The privatization of agricultural research risks sidelining public-sector breeding programs that have historically supported food security.

Conclusion

India's patent issues and seed monopolies underscore the urgent need for a balanced legal and policy framework that fosters innovation while protecting farmers' rights and biodiversity. Strengthening enforcement of the PPVFR Act, revisiting patentability norms with government participation, and ensuring inclusive stakeholder dialogue are critical steps forward. The future of Indian agriculture depends on harmonizing intellectual property rights with sustainable farming practices to secure food sovereignty and equitable access to technology.

ISSN : 2583-0910
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monthly newsletter

Article ID : 05/VIII/35/0825

PHYTOMICROBIOME DYNAMICS IN SPICE AND MEDICINAL CROPS

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Abstract

The plant microbiome, or *phytomicrobiome*, encompasses the complex assemblage of microorganisms associated with plant tissues and their surrounding microenvironment, collectively influencing plant physiology, health, and productivity. In spices and medicinal plants, these microbial consortia significantly contribute to growth promotion, stress tolerance, and biosynthesis of bioactive secondary metabolites that define the therapeutic, aromatic, and flavoring qualities of these crops. Recent advances in metagenomics, transcriptomics, and metabolomics have deepened our understanding of plant–microbe interactions and their functional roles in enhancing phytochemical properties.

Keywords: phytomicrobiome, microorganisms, secondary metabolites, microbial consortia

Introduction

The plant microbiome, also known as the phytomicrobiome, plays roles in plant health and productivity and has received significant attention in recent years. The microbiome has been defined as a characteristic microbial community occupying a reasonably well-defined habitat which has distinct physio-chemical properties. Plants live in association with diverse microbial consortia. These microbes, referred to as the plant's microbiota, live both inside (the endosphere) and outside (the episphere) of plant tissues, and play important roles in the ecology and physiology of plants.

Functions of plant microbiota

Biological nitrogen fixation

Biological nitrogen fixation (BNF) is a key process wherein plant associated bacteria convert atmospheric nitrogen into a usable form of ammonia for plants. Nitrogen fixation reduces the need for synthetic nitrogen fertilizers which are environmentally detrimental Furthermore, non-nodular bacteria like *Gluconacetobacter diazotrophicus* have expanded the scope of BNF to non-leguminous plants.

Mineral solubilization

Phosphate-solubilizing bacteria (PSB) convert insoluble phosphate into bioavailable forms through organic acid production. Similarly, potassium-solubilizing bacteria (KSB) enhance the availability of potassium, critical for plant water regulation and enzyme activation. For example, *Bacillus megaterium* and *Pseudomonas fluorescens* have been shown to effectively solubilize phosphate, improving plant growth in phosphorus-deficient soils.

Phytohormone production

Plant-associated bacteria, particularly from the genera of *Bacillus* and *Pseudomonas,* are capable of producing phytohormones such as auxins, cytokinins, and gibberellins. These hormones regulate critical aspects of plant development, including cell division and elongation. *Bacillus* *megaterium* is a prolific producer of indole-3-acetic acid (IAA), a key auxin that enhances root growth and nutrient uptake.

Phytohormone regulation through ACC deaminase activity

Ethylene, a plant hormone produced in response to stress, can inhibit plant growth. Certain bacteria mitigate the negative effects of ethylene by producing the enzyme 1-aminocyclopropane-1- carboxylate (ACC) deaminase, which breaks down ACC, the ethylene precursor. These ACC deaminase-producing bacteria not only promote plant growth but also improve tolerance to environmental stresses like drought and salinity.

Siderophore activity

Siderophores are iron-chelating compounds produced by bacteria and fungi to solubilize and transport iron in iron-limited environments. *P. fluorescens* and *B. subtilis* produce siderophores such as pyoverdine and bacillibactin, which improve iron acquisition in plants. This activity not only enhances plant growth but also provides biocontrol against pathogens by limiting their access to iron, an essential nutrient.

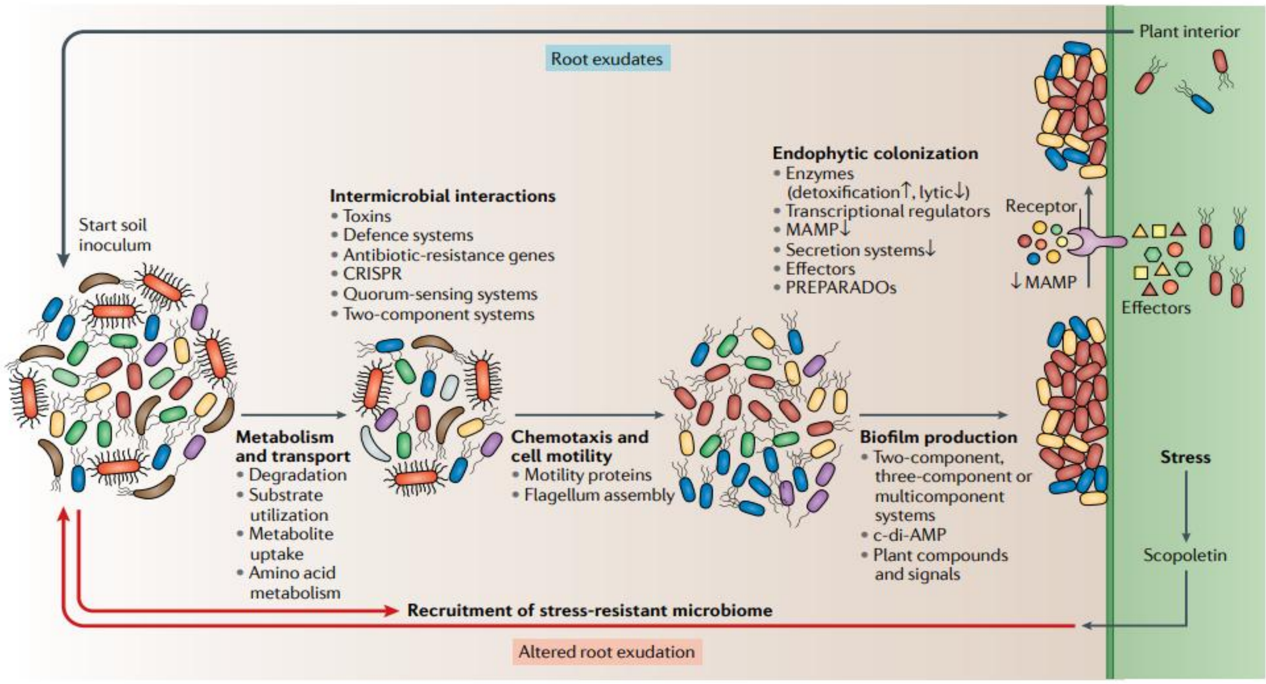
Exopolysaccharide and biofilm formation:

Exopolysaccharides are high-molecular-weight polysaccharides secreted by bacteria that form biofilms. EPS production facilitates bacterial adherence to plant roots, enhancing nutrient and water uptake. Biofilms protect the microbial community from environmental stresses, such as desiccation and salinity, and can also protect against pathogens by forming a physical barrier and competing for resources.

Plant-microbiome interactions:

The plant interacts with the microbiome through the release of root exudates (for example, organic acids, sugars and secondary metabolites) throughout its developmental stages. The microorganisms in the bulk soil act as 'seed banks' and vary in their genomic potential to degrade, utilize and metabolize distinct metabolite substrates in the root exudate. Signalling events mediated by quorum sensing or other two-component systems have a key role in both inter-microbial and intra-microbial communications among different species. CRISPR-associated genes provide adaptive immunity against bacteriophages and are under strong selection pressure in plant-associated microbiomes.

The presence of antibiotic-resistance genes may provide protection against biological and chemical warfare (for example, toxins and defence systems) that occurs during the initial stages of community assembly. Subsequently, the microbial community moves towards the plants through chemotaxis, involving motility proteins and the assembly of flagella. Further colonization is mediated through sophisticated communications between plants and microbial communities, leading to the formation of a biofilm on plant surfaces. The second messenger cyclic di-adenylate monophosphate (c-di-AMP) mediates interbacterial cell–cell communication and the initiation of biofilm formation by influencing the expression of genes involved in biofilm production. Genes involved in motility, chemotaxis, adhesion and biofilm production further contribute to plant colonization and the endophytic lifestyle within the host plant.



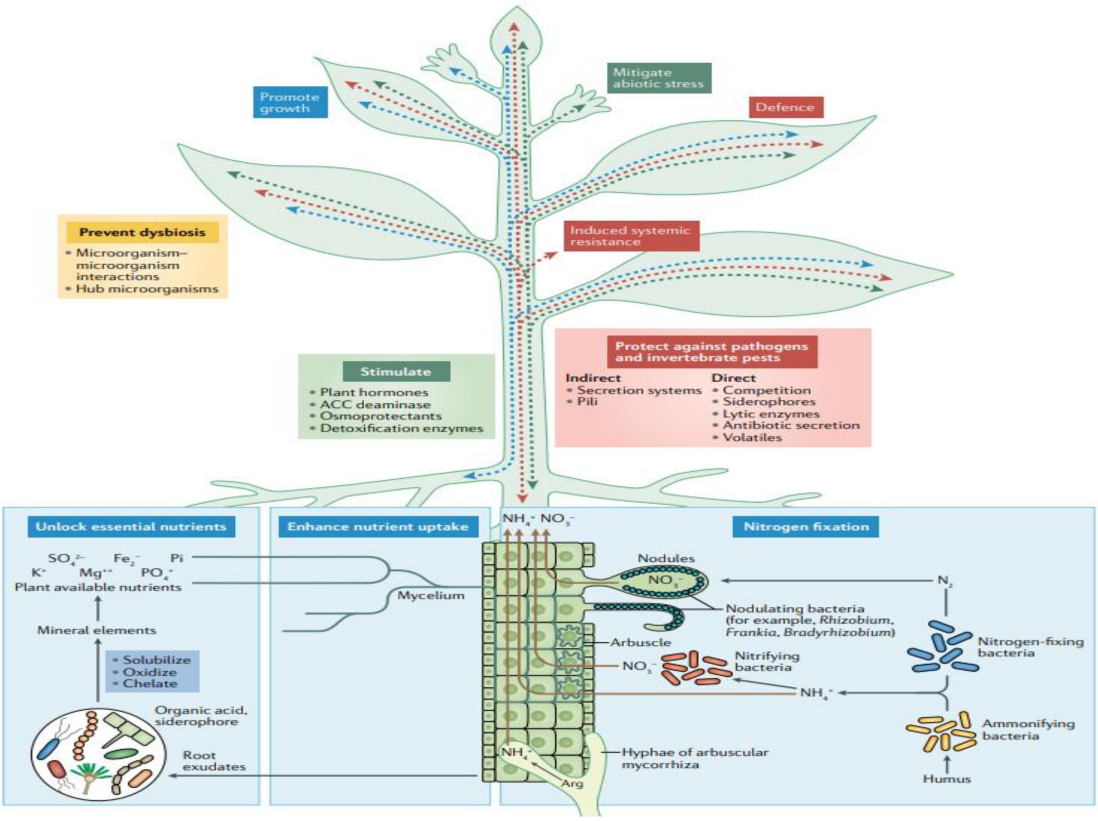
Trivedi *et al.*, 2020

Fig-1 : Plant-microbiome interactions

Suppression of plant-produced reactive oxygen species by microbial detoxification enzymes such as superoxide dismutase, catalase, peroxidase, alkyl hydroperoxide reductase and glutathione-S-transferase facilitates initial endophytic colonization. Entry into plant tissues is facilitated by the production of lytic enzymes such as lysozymes or cell-wall degrading enzymes. It is postulated that endophytes produce low levels of lytic enzymes as compared with pathogens, thus avoiding triggering the plant immune response. Diversification of microbial-associated molecular patterns (MAMPs) circumvents recognition by the plant immune response and is likely to shape endosphere microbial assemblages in plant populations. Overall, the interplay between plants and their endophytic microbiota is complex and still far from being fully elucidated.

Beneficial effects of the plant-associated microbiome

Diazotrophic bacteria can fix atmospheric nitrogen (N_2) and might actively transport ammonium (NH_4^+) and nitrate (NO_3^-) to the host. Ammonifying bacteria convert organic N_2 present in the soil to NH_4^+, which is further converted to NO_3^- by nitrifying bacteria. Leguminous plants develop root nodule symbiosis with N_2-fixing bacteria. Arbuscular mycorrhizal fungi convert arginine (Arg) to urea and then to NH_4^+. Microbiomes can unlock essential elements by oxidizing, solubilizing or chelating minerals into plant-available nutrients such as phosphate (Pi), nitrogen (NH_4^+) and potassium (K^+) through the production of organic acids and siderophores. Furthermore, arbuscular mycorrhizal fungi might enhance nutrient availability by long-distance transport through the mycelium and specialized structures called arbuscules (fungal hyphae ensheathed in a modified form of the cortical cell plasma membrane) that transport elements directly to the host cytoplasm. Microbiomes can stimulate plant growth by metabolizing tryptophan and other small molecules in the plant exudates and producing phytohormones that include auxins, gibberellins, cytokinins and phytohormone mimics.



Trivedi *et al*. (2020)

Fig-2 : Beneficial effects of the plant-associated microbiome

Auxins can also induce transcription of the ACC synthase that catalyses the formation of ACC. ACC, the direct precursor of ethylene, is metabolized by bacteria via the enzyme ACC deaminase, thus ameliorating abiotic stress. Members of plant-associated microbiomes produce a range of enzymes that can detoxify reactive oxygen species, thus minimizing plant-induced stress. The plant-associated microbiome protects the plant against pathogens by the production of antibiotics, lytic enzymes, volatiles and siderophores. Interkingdom and intrakingdom interactions within the microbiome maintain the microbial balance, thus protecting plants from dysbiosis. Furthermore, hub microorganisms can amplify host signals in order to promote the assembly of a microbiome that provides benefits to the plant.

Functions of Plant Microbiomes in Spices and Medicinal Crops

A. Nutrient Acquisition and Soil Fertility

Beneficial microbes help in nitrogen fixation, phosphorus solubilization, and potassium mobilization, making essential nutrients available to plants.

Example:

- Rhizobium species in legumes enhance nitrogen fixation.
- *Pseudomonas* and *Bacillus* species solubilize phosphorus in soil, aiding plant uptake.

B. Enhancement of Growth and Yield

Plant growth-promoting rhizobacteria (PGPR) secrete phytohormones such as auxins, gibberellins, and cytokinins, which improve root architecture and overall plant growth. Mycorrhizal fungi form symbiotic relationships with roots, improving water and nutrient absorption.

C. Disease Suppression and Pest Control

Certain microbes act as biocontrol agents, inhibiting plant pathogens through competition, antibiosis, or induced plant defense mechanisms. Ex: Trichoderma fungi protect spice crops like black pepper and turmeric from fungal diseases. *Bacillus subtilis* produces antimicrobial compounds that suppress soil-borne pathogens.

D. Stress Tolerance (Abiotic and Biotic Stress)

Microbiomes help plants survive under drought, salinity, temperature fluctuations, and heavy metal toxicity by enhancing root structure and activating stress response pathways. Example: Arbuscular mycorrhizal fungi (*Glomus* species) improve water retention in turmeric and ginger.

E. Enhancement of Secondary Metabolite Production

Many spices and medicinal plants produce bioactive compounds such as alkaloids, flavonoids, terpenoids, and phenolics, which have antimicrobial, anti-inflammatory, and antioxidant properties. Microbes influence the biosynthesis of these compounds, thereby increasing their medicinal and nutritional value. Example: Endophytic fungi in medicinal plants like Ashwagandha (*Withania somnifera*) enhance withanolide production. Rhizobacteria in turmeric enhance curcumin biosynthesis.

Table:1- Microbiome Associations in Key Spices and Medicinal Crops:

Crop	Key Microbial Associations	Functions
Turmeric (*Curcuma longa*)	*Bacillus*, *Pseudomonas*, mycorrhizal fungi	Disease resistance, curcumin production, nutrient absorption
Ginger (*Zingiber officinale*)	*Trichoderma*, *Glomus*	Protection against fungal infections, improved drought resistance
Black Pepper (*Piper nigrum*)	*Bacillus subtilis*, *Trichoderma*	Root health, biocontrol of fungal pathogens
Clove (*Syzygium aromaticum*)	*Actinobacteria*, mycorrhizae	Stress tolerance, antimicrobial metabolite enhancement
Ashwagandha (*Withania somnifera*)	Endophytic fungi, *Bacillus* spp.	Withanolide production, pest resistance
Holy Basil (*Ocimum sanctum*)	*Pseudomonas*, *Azospirillum*	Enhanced eugenol biosynthesis, growth promotion

Conclusion

Plant microbiomes play a crucial role in sustainable agriculture by fostering diverse and beneficial microbial communities that contribute to plant health and productivity. Although microbial inoculants have been developed to enhance plant growth and resilience, their effectiveness in real-world agricultural settings has been inconsistent. This underscores the urgent need for targeted strategies to optimize microbial selection, formulation, and delivery methods to improve field performance. Innovative approaches such as encapsulation technologies and seed microbiome modulation show promise in enhancing microbial colonization and persistence, bridging the gap between laboratory research and practical application in agricultural settings. Future research should focus on filling knowledge gaps related to how inoculants impact existing microbiomes, the functional dynamics within complex microbial communities, and the factors influencing microbial colonization in agricultural settings.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/36/0825

Pichhora: THE HERITAGE DRAPE OF KUMAUNI WOMEN

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Abstract

Uttarakhand is home to diverse plant and animal life, winding rivers, mist-filled valleys, snow-capped summits, and elusive glaciers. Many of the arts and crafts that Uttarakhand is have long created and fostered have been impacted by this pristine natural beauty of Uttarakhand is divided into two regions: Kumaon and Garhwal. The rich cultural legacy and varied communities that call Uttarakhand home can be better understood through the region's traditional attire. Among these, the *Pichhora* holds a special place as a sacred veil worn by married women during auspicious occasions like weddings, naming ceremonies, and housewarming rituals. Originating during the Chand dynasty's rule in the 12th century, the *Pichhora* not only signifies a woman's marital status but also embodies the cultural identity and traditions of Kumauni women. Despite evolving fashion trends, it remains an integral part of Uttarakhand's cultural legacy, worn with pride during religious and social ceremonies, reflecting the state's deep-rooted connection to its heritage. This review paper, describes the historical origins, cultural significance, and traditional craftsmanship of the *Pichhora*. Along with symbolic motifs, colours, and the techniques used in creation of *Pichhora,* as well as its role in representing marital status and cultural identity. Additionally, its enduring relevance in contemporary times, emphasizing its importance as a symbol of Uttarakhand's rich cultural heritage and its continued use in traditional ceremonies is also highlight. This paper aims to provide a comprehensive understanding of the *Pichhora's* profound cultural and social significance in the lives of the people of Uttarakhand.

Key words : Traditional attire, *Pichhora*, pichhoda, Rangwaali, odhani, Kumauni

Introduction

Indigenous tribes, cultural diversity, and a variety of customs all contribute to Uttarakhand's strength. It is well-liked by tourists because of its rich biodiversity and pilgrimage sites. The state's rich legacy is enhanced by its most treasured cultural emblems, Pichhora also known as kumaus Rangwaali Pichhoda (Somlata & Sarkar, 2024).

Women in Kumaon traditionally dress in Ghaghara, a full-sleeved shirt, and a scarf. In addition, a traditional aanchal or dupatta known as pichhora is an important part of Uttarakhand's culture, worn by married women as a sacred veil on auspicious occasions such as weddings, Janeu Sanskar, naming ceremonies, and housewarming rituals. It has a unique meaning in expressing a woman's marital status. Widows may wear it as well, but according to societal custom, they are not allowed to wear colourful clothing. Women, wear the pichhora even if they are dressed in pricey designer saris. Even today, Uttarakhand's people maintain their traditional jewelry, attire, and culture (News Desk,2022).

The term pichhora, comes from the Hindi word pichh, which means back, refers to a long scarf that is and worn over the shoulders. It is a chunni, about 1.25 meters in width and 2.75 or 3 meters in length. Chikan cloth is used to colour it, and it is painted red on a yellow backdrop. Its vivid orange or yellow color is frequently accentuated by maroon or scarlet motifs and dots. In the past, skillful women utilized a 25 paise coin to create the Swastik and other shapes. The 25 paise coin was employed in an upright form to create the swastik and other geometric designs, and it was simply laid on the cloth to create dots. The diverse fabric of Kumauni life may be reflected in other designs that incorporate natural elements, celestial bodies, and cultural symbols (Chouhan, 2022; Suchira).

The traditional accessories worn by women, particularly married women in ethnic Uttarakhandi households, are what give Pichhora its significance. All Uttarakhand traditional brides wear the Pichhora because it is seen as devout and because the colors red and saffron represent wealth and good fortune. During every religious ceremony held in a typical Uttarakhandi home. Women proudly don the attire known as Rangwali Pichhora (Lohumi, 2023).


Laces


Motifs


Brides odhani

Source
Laces : https://www.amazon.in/Designer-Uttarakhand-Traditional-Kumaoni-Pichodi/dp/B09HDHYZJJ
Motifs : https://www.indiatravel.app/uttarakhand-traditional-dress-male-and-female/
Brides odhani : https://www.culturaltrends.in/wp-content/uploads/2022/02/Print3-860x674.jpg

Origin of *Pichhora*

According to historical records, pichhora was a common courtly garment worn by Rajput queens during the Middle Ages. Although still no exact documentation of Pichhora's origin, it is thought to have its origins in Kumaon during the Chand dynasty's control in the 12th century. The Chand kings were renowned for their encouragement of the arts, and a thriving cultural landscape encompassing weaving, embroidery, and painting developed during their rule. This period gave rise to Pichhora, which was made by gifted women utilizing natural materials and age-old methods. Traditionally, rural women made pichhora by dyeing cotton fabric with turmeric and vermillion. Pichhora manufacturing became more uniform, and manufacturers started utilizing contemporary techniques as the market expanded (Arya, 2009; Lohani, 2019).

The Significance of Colors and Motifs in Pichhora Design

Color : For Kumauni women, the hues and designs on *Pichhora* hold particular significance. Red or maroon symbolizes passion and love, whereas yellow or orange is linked to warmth and happiness.

Motifs

- The ***Swastika*** signifies the spirit of *Karma Yoga* in mankind and is a symbol of deities. Its four arms stand for wealth and health.
- ***Om*** is seen as a symbol of consciousness and spiritual existence at the very center of the Swastika.
- ***Sun*** first quadrant of swastika's, stands for a son's contentment and wealth.
- The ***moon*** represents elegance and beauty.
- The ***Bell*** which is positioned in the second quadrant, represents affluence, happiness, dedication and fortune.
- The ***Conch*** *(Shankha)* in the third quadrant signifies religion, knowledge and purity.
- In the fourth quadrant, **Goddess Lakshmi** stands for wealth and luxury (Singh, 2024).

Conventional and Contemporary Approaches to Making Pichhora

Traditional method

It was manufactured at home in the past. After washing and first dying a few meters of white fabric in yellow, dots were printed using a cloth-wrapped coin. Rapid colors are now being used instead of the common colors that were previously used for it (Lohani, 2019).

Morden method

Contemporary method of production involves the use of "Hakoba embroidered cloth." The material is thoroughly cleaned in order to remove the starch. It is then given another wash and dyed yellow. After that, printing is done on wooden blocks. These blocks create patterns and are carved with all the geometry and sketches created in *Pichhora*. Lace is stitched around the edges after the proper printing and drying process, and then a shimmering kinari or jhalar is stitched (Arera, 2021).

***Pichhora* in the Contemporary World**

Although modernization and machine production have replaced the hand-painted tradition, the faith, emotions, and unity associated with *Pichhora* remain unchanged. Today, *Pichhora* is widely promoted through songs, social media, and advertisements, keeping its cultural significance alive (News Desk, 2022; Singh, 2024).

With its growing popularity, *Pichhora* is now available in stores across Uttarakhand and other metropolitan cities like Delhi and Mumbai, and even abroad. However, traditional hand-painted *Pichhoras* are still crafted in places like Almora, Ranikhet, and Dwarahat. In modern times, both married and unmarried women wear *Pichhora*, blending it with contemporary fashion while staying rooted in their traditions. It serves as a symbol of Kumaoni identity, preserving the cultural, historical, and religious essence of the region (Lohumi, 2023).

Pichhora continues to be a perfect blend of heritage and modernity, with its unique designs, vibrant colors, and intricate artistry mesmerizing people and drawing tourists' attention.

Conclusion

The *Pichhora*, a sacred veil from Uttarakhand, symbolizes the region's rich cultural heritage and traditions. Originating in the 12th century during the Chand dynasty, holds deep significance for married *Kumauni* women, representing marital status, spirituality, and cultural identity. Adorned with vibrant colors and motifs like the Swastika, Om, and Goddess Lakshmi, it reflects the values and natural beauty of Uttarakhand. Despite modern fashion trends, the *Pichhora* remains a cherished part of religious and social ceremonies, connecting generations and preserving the region's legacy. It is not just attire but a cultural emblem, embodying the spirit and traditions of Uttarakhand for future generations.

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Uttarakhand traditional dress: A peek into the tradition of Devbhoomi. *Didi Bhula*.

Article ID : 05/VIII/37/0825

NANO-SHIELDED FRESHNESS: EDIBLE NANOCOMPOSITE COATINGS TO EXTEND POSTHARVEST LIFE OF PERISHABLE FRUITS

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Abstract

Climacteric fruits like mango (*Mangifera indica* L.) suffer rapid spoilage, driving global postharvest losses. Alginate-based edible coatings reinforced with 0.5 zinc oxide nanoparticles (ZnO-NPs) offer a sustainable preservation strategy. ZnO-NPs enhance moisture and gas barriers and provide antimicrobial action, reducing respiratory rates by 25% and limiting weight loss to under 4% during 35 days at 13 °C. Coated fruit maintained 80% initial firmness, moderated total soluble solids increase, and preserved total carotenoids and phenolics at 30% above uncoated controls. Decay incidence fell by ≥2 log CFU g^{-1}, while zinc migration remained below Codex limits. Key factors for commercial adoption include controlled-release kinetics, scalable application, and environmental impact assessment. Alginate–ZnO-NP coatings thus present a clean-label alternative to synthetic waxes and fungicides for extending mango shelf life.

Keywords: Edible coatings, zinc oxide nanoparticles, alginate nanocomposite, postharvest preservation.

Introduction

There are serious environmental and economic issues with the quick deterioration of extremely perishable fruits like mangoes and strawberries. Conventional synthetic waxes and chemical preservatives pose health and environmental hazards (Borah *et al.,* 2025). A promising substitute is provided by edible coatings composed of biopolymers and strengthened with nanomaterials, which produce active "nano-shields" that control microbial activity, gas exchange, and moisture (Arroyo *et al.,* 2020). For creative packaging, electrospun nanofiber membranes provide a tunable barrier and functionalization capabilities (Mathew *et al.,* 2025). Karimi Dehbakri *et al.,* (2025) state that coatings made of nanocellulose and zinc-oxide nanoparticles (ZnO-NP) prolong shelf life, retain nutritional qualities, and preserve quality. This article combines two example studies; alginate–ZnO-NP coatings on mangoes and nanocellulose essential-oil coatings on strawberries—to show how edible nanocomposite films can preserve fruit quality and extend shelf life (Jahani & Biglari, 2025).

Case Study I: Nanocellulose–Essential-Oil Coatings on Strawberry

Myrtle essential oil (MEO) and α-pinene (AL) at 0.3% and 0.6% were added to nanocellulose-based coatings, which Karimi Dehbakri *et al.,* (2025) tested on Fragaria x ananassa over 18 days at 4°C. Nano-MEO 0.6% and Nano-AL 0.6% were used as treatments; nanocellulose and oil were absent from the controls.

Loss of Weight and Firmness: While maintaining firmness at 1.2 N at day 18 compared to 0.6 N in controls, Nano-MEO 0.6% decreased cumulative weight loss to about 13% from 32%. The semi-permeable barrier that the nanocellulose matrix creates slows down softening and limits transpiration (Karimi Dehbakri *et al.,* 2025).

Bioactive Retention: Ascorbic acid in Nano-AL 0.6% was more than four times the control, reaching 85 mg 100 g^{-1} FW. In AL, 0.6% total anthocyanins peaked at around 27 mg 100 g^{-1} FW, while in controls, they peaked at about 8 mg 100 g^{-1} FW. Barriers made of nanocellulose prevent vitamins and pigments from degrading due to light and oxygen.

Antioxidant Phenolics & Enzymes: Nano-MEO 0.6% maintained elevated catalase and peroxidase activity, which decreased reactive oxygen species buildup and delayed senescence. On day 18, the total phenolics in Nano-MEO were 0.3%, and enzymatic browning was reduced by 35% above the controls, per Karimi Dehbakri *et al.,* (2025).

Sensory Acceptability: Nano-MEO 0.6% of the fruits received top ratings from the panelists for long-term flavor retention and visual freshness. Coatings hid moisture loss without adding unpalatable flavors.

Implication: By acting as active coatings that supply antibacterial and antioxidant agents and improve barrier qualities in concert, nanocellulose–essential-oil composites significantly increase the marketability of strawberries.

Case Study II: ZnO nanoparticles were incorporated into 0.5% sodium-alginate coatings by Hmmam *et al.,* (2023) to preserve *Mangifera indica* cv. Kiett for 35 days at 13°C, followed by shelf life.

Weight Loss and Respiration: Alg-ZnO-NP coatings decreased the weight loss to less than 4% and decreased respiratory rate peaks by 25% compared to uncoated fruit, which lost roughly 9% of its weight over five weeks. By enhancing the polymer network, ZnO-NPs enhance gas-diffusion control (Hmmam *et al.,* 2023).

Soluble Solids and Firmness: At day 35, coated mangoes maintained 80% of their original hardness, more than the 50% retained by controls. The progressive increase in total soluble solids prevented overripening and preserved a balanced TSS/TA ratio.

Nutraceutical Preservation: Because of less oxidative degradation, the total carotenoids and phenolics in Alg–ZnO-NP fruits were 30% higher than in controls throughout storage. Additionally, ZnO's antibacterial activity reduced the incidence of decay by 2 log CFU g^{-1} (Hmmam *et al.,* 2023).

Safety and Regulatory: Migration assessments have shown that zinc migration stays well under Codex limits, underscoring these coatings' qualification as food-grade.

As a result, alginate films infused with ZnO nanoparticles serve as physical barriers and deliver antibacterial protection, effectively preserving the quality of climacteric fruits throughout extended cold-chain transport.

Discussion

Both studies demonstrate that nanocomposite edible coatings (Karimi Dehbakri *et al.,* 2025; Hmmam *et al.,* 2023):

1. **Enhance Barrier Properties:** Nanocellulose and ZnO-NPs strengthen polymer matrices, reducing moisture loss and gas exchange.
2. **Deliver Bioactive Agents:** Essential oils and ZnO-NPs confer antimicrobial, antioxidant, and ethylene-scavenging functionalities.

3. **Preserve Nutritional & Sensory Quality:** Vitamins, phenolics, and firmness are maintained well beyond control levels, with positive consumer acceptability.

Optimizing the controlled release kinetics of bioactives under varying temperature and humidity conditions and performing life-cycle assessments to compare environmental impacts with traditional treatments are two important research gaps (Wardana *et al.,* 2025).

Conclusion

An eco-friendly and consumer-friendly way to increase the postharvest life of perishable fruits is to apply edible nanocomposite coatings. Combining biopolymers with essential oils or functional nanoparticles avoids oxidative deterioration, microbial spoiling, and moisture loss. Reducing food waste, improving supply-chain resilience, and satisfying consumer demand for clean-label preservation are all anticipated benefits of scaling these technologies from laboratory to commercial implementation.

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ISSN : 2583-0910
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/38/0825

SEED TRACEABILITY : ROLE AND ITS BENEFITS

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Abstract

Seed is basic input in agriculture. Seed play an important role in crop production and yield of the crops. Crop production depends on the seed so the seed quality is an important for maximizing yield of the crops. Quality seed ensures the increasing production with higher yield and helps in increasing the profit for the farmers. The traceability system of seed ensures the quality of seed its origin of production to protect farmers from spurious kind of seeds. This article highlights the traceability of seed its role and benefits for farmers.

Key Words: Seed traceability, Seed quality, Transparency, Benefits

Introduction

Seed is not merely viewed as the cornerstone of agriculture; they should also be regarded as emblems of identity, life, nutrition, culture, and climate resilience. Seed is basic input to the agriculture. Most of the small-scale farmers rely on market-driven hybrid seeds (The Hindu, 2025). Traceability is essential for guaranteeing the quality and authenticity of seeds, which is vital for improving agricultural productivity and to provide livelihoods to millions of farmers.

The seed traceability process involves monitoring the seed's chain from its origin through production, processing, and distribution, thereby helping to prevent the dissemination of counterfeit seeds and ensuring that farmers have access to high-quality and certified seeds. The traceability of seeds by Quick Response codes gives detail, and it encompass details regarding who are the producer of the seed, when and where it was produced, its date of expiry, processing and packaging with dates.

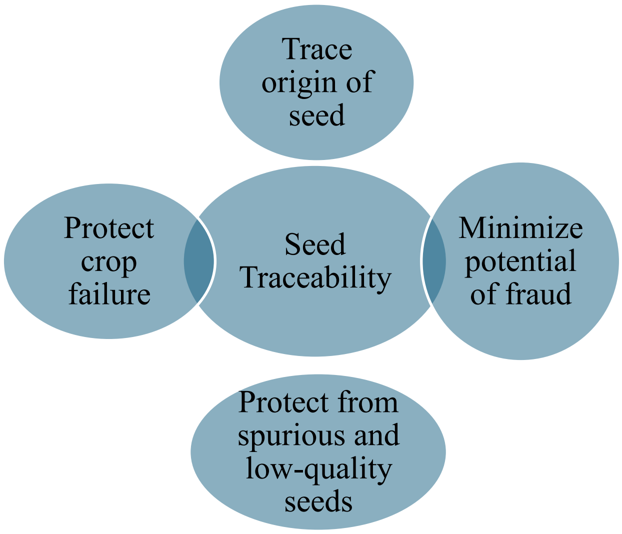
Seed Quality

Quality seeds are among the most critical inputs to agriculture for boosting crop productivity. Since seeds are the carriers of any innovative technology, it is imperative to verify their quality for end users and farmers. Quality guarantee is important at each stage of value chain; consist of production of seed, processing of seed, packaging, storage of seed, and it distribution. Seed traceability with help of advance technologies facilitates quality assurance throughout each stages of seed production and can be easily rectified if any chance of errors. A Seed Traceability system helps to guarantee the availability of high-quality seeds for farmers. The traceability system aims to reduce robbery in the seed trade sector and it benefits both for farmers and individuals working within the seed industry. The seed chain begins with the breeder to the foundation and certified seed. Efforts have commenced to digitalize the distribution and its value chain in coming time. With one segment nearly finished, the subsequent focus is to capture the distribution network, ensuring that any farmer can access the necessary resources.

Seed Traceability and its Benefits

The seed traceability System represents a new initiative introduced by the government of India aimed at ensuring that farmers have access to high-quality seeds while also addressing issues of stealing within the seed trade sector. Traceability system allows farmers to trace the origin of their seeds, thereby enhancing transparency in the seed trade and minimizing the potential for fraud. The seed traceability system is designed to benefit farmers by enhancing both crop yield and quality, as well as decreasing the likelihood of crop failure due to inferior seeds.

Fig. 1: Benefits of Seed Traceability



Transparency and Reliability

Seed traceability systems may offer complete transparency throughout the seed supply and its value chain. To enhance the transparency and reliability of the seed supply chain, traceability systems provide real data and information at every level and facilitate a responsive process, assisting relevant agencies in collecting profits and ensuring a high-quality seed to strengthen both the national and international seed markets (Paul *et al*, 2024). To combat the presence of spurious and low-quality seeds. Seeds available in the market frequently contain undesirable inputs, pose health risks, and incur high costs, which have made farming practices less profitable.

Government initiatives

The SATHI (Seed Traceability, Authentication and Holistic Inventory) Portal and mobile app have been launched as a centralized online system for seed traceability, authentication, and inventory, specifically designed to address the risk associated with production of seed, quality seed identification, and certification detail of seed. The SATHI portal ensures quality assurance system that identifies the source of seeds within the seed production chain. The system likely encompass seven integrated verticals of the seed chain, research organization; seed certification, seed licensing, seed catalogue, dealer to farmer sales, and farmer registration.

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ISSN : 2583-0910
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Article ID : 05/VIII/39/0825

SILKWORM BREEDING: INDIA'S LEAP TOWARDS SUPER SILKWORMS

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Introduction

India is pioneering a new era in sericulture by breeding "super silkworms" using advanced scientific techniques. With a rich history of silk production, India ranks among the world's top silk producers but faces challenges like disease, low yield, and inconsistent silk quality. Researchers are combining traditional breeding with biotechnology to develop silkworms that yield more silk, are disease-resistant, and adapt better to diverse climates. These improved silkworms produce stronger, finer, and more lustrous silk, helping meet rising global demand sustainably. Collaboration between research institutes, the government, and farmers is accelerating the adoption of these new breeds. This innovation not only boosts productivity but also empowers rural livelihoods and promotes eco-friendly practices. Enhanced silkworm breeding aligns with India's goal to increase silk exports and compete globally. Such advancements promise to modernize the sector while preserving India's silk heritage. Ultimately, India's "super silkworms" mark a major step toward transforming sericulture into a high-tech, sustainable industry. This leap holds significant potential for socio-economic growth and environmental conservation.

Figure 1. Silkworms and cocoons

Why Super Silkworms?

Traditional silkworm breeds in India have long struggled with issues such as disease susceptibility, low yield, and sensitivity to climatic fluctuations. These limitations directly impact farmer incomes and the competitiveness of Indian silk on the global stage. The development of robust, high-yielding, and climate-resilient silkworm varieties often termed "super silkworms" is seen as essential for ensuring both economic and environmental sustainability in sericulture (Ashraf & Sajid, 2023).

Breakthroughs in Silkworm Breeding

Recent breakthroughs in silkworm breeding have emphasized the exploitation of hybrid vigor through the development of bivoltine hybrids and region-specific crossbreeds. Prominent examples include PM × CSR2, which is suitable for all seasons in South and Central India; CSR2 × CSR4, adapted for South India and favorable seasons elsewhere; and FC1 × FC2, which performs well across most Indian regions in suitable seasons. These hybrids offer significant advantages such as higher cocoon yields, improved disease resistance, and superior yarn quality. Field studies in India have demonstrated that hybrid silkworms like PM × CSR2 and FC1 × FC2 fed on tree mulberry outperform those reared on bush mulberry, showing significantly greater larval and cocoon weights, shell ratios, and cocoon yields per 100 disease-free layings (Vanitha & Narayanaswamy, 2019). In addition, recent research underscores the need to select stable and heat-resistant genotypes in light of increasing high-temperature events due to climate change. Tropical multivoltine breeds such as Pure Mysore and Nistari have shown greater resilience to heat stress, making them valuable genetic resources for future breeding programs (Abdukadirov *et al.,* 2024).

Genomic Advances and the Science Behind Super Silkworms

Recent genetic advances in Indian silkworm breeding have rapidly accelerated the development of robust, high-yielding, and climate-resilient silkworm lines by integrating molecular tools such as marker-assisted selection (MAS), which enables breeders to identify and select individuals carrying desirable genes for traits like thermotolerance, disease resistance, and silk productivity with greater speed and precision than conventional methods. Marker-assisted backcross breeding (MABB) further refines this process by allowing the targeted introgression of specific genes into elite backgrounds while retaining overall genetic integrity, thus combining multiple beneficial traits in fewer generations (Li *et al.,* 2015). Genomic selection leverages genome-wide marker data and predictive modeling to simultaneously improve complex, polygenic traits such as silk yield and stress tolerance, greatly enhancing selection efficiency and accuracy (Chandrakanth, 2024; Maheswari *et al.,* 2023). Speed breeding, which combines controlled environment rearing with rapid generation cycling and molecular selection, enables breeders to quickly fix favorable alleles in silkworm populations, significantly shortening the breeding timeline and supporting the rapid release of new, improved hybrids suited to India's diverse agro-climatic zones (Chandrakanth, 2024; Maheswari *et al.,* 2023; Suresh, 2023). These cutting-edge strategies, championed by institutions like the Central Silk Board, are ensuring that Indian sericulture remains globally competitive and resilient in the face of evolving environmental and market challenges (Central Silk Board, 2011; Ministry of Textiles, 2023).

Farmer-Centric Innovations and Economic Impact

The adoption of super silkworms is already translating into tangible benefits for Indian farmers. Higher yields, shorter rearing cycles, and improved disease resistance mean increased incomes and reduced risks. For example, isolating short larval duration lines in Oak Tasar silkworms can reduce rearing time by up to 10 days and increase cocoon production by 12–16% (CMERTI, 2025). Polyamine treatments are being tested to enhance fecundity and egg production in muga and eri silkworms, potentially solving seed supply challenges.

Policy Support and Future Vision

Government initiatives, such as the Silk Samagra-2 program, are supporting infrastructure development, research, and technology transfer to ensure that India remains a global leader in silk production (Ministry of Textiles, 2023). With a clear focus on sustainability and farmer welfare, the vision is to make India synonymous with high-quality, eco-friendly silk.

Challenges and the Road Ahead

India's silkworm breeding efforts face ongoing challenges despite advances in developing super silkworms. Climate change leads to erratic weather, affecting silkworm health and mulberry cultivation. Water scarcity stresses mulberry crops, critical for silkworm nutrition. The sector also suffers from limited skilled manpower and insufficient farmer training, slowing technology uptake. Disease outbreaks and new pests threaten silkworm populations and silk quality. Additionally, outdated reeling technology and unorganized processing units cause quality inconsistencies. Urbanization reduces mulberry-growing land, further limiting raw material supply. To address these, continuous research and development of region-specific silkworm breeds are vital. Strong government support, infrastructure modernization, and private-sector partnerships are also needed. Collaboration among scientists, farmers, and industry stakeholders is essential to sustain India's progress toward super silkworms and a globally competitive sericulture industry.

Conclusion

India's journey in silkworm breeding is a testament to the power of scientific innovation and collaborative effort in transforming traditional industries. By embracing cutting-edge genetic tools such as marker-assisted selection, genomic selection, and speed breeding, Indian sericulture is rapidly evolving to meet the challenges of climate change, disease pressures, and global market demands. The leadership of the Central Silk Board, robust policy support, and the dedication of researchers and farmers are ensuring that new, resilient, and high-yielding silkworm hybrids reach the fields where they are needed most. As these "super silkworms" become the backbone of sustainable silk production, India is poised not only to retain its legacy as a global silk leader but also to set new standards for quality, productivity, and environmental stewardship in the years to come. The future of Indian silk is brighter, stronger, and more sustainable woven from the threads of science, tradition, and innovation.

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ISSN : 2583-0910
Agri-India TODAY
visit us at www.agriindiatoday.in
Peer reviewed monthly newsletter

Article ID : 05/VIII/40/0825

SOLAR TUNNEL DRYERS IN DRY FISH PRODUCTION : PROS AND CONS EXPLAINED

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Introduction

Dry fish production is a vital livelihood and food preservation method in many coastal and inland fishing communities. Traditionally, fish are dried using open sun drying methods, which are simple but come with challenges such as contamination, weather dependence, and uneven drying. To address these issues, solar tunnel dryers have emerged as an efficient, sustainable, and hygienic alternative. Solar tunnel dryers use controlled solar energy in an enclosed system to reduce moisture content in fish while protecting it from dust, insects, and rain (Al-Saadi, 2021). This technology not only improves the quality and shelf life of dry fish but also supports small-scale fishers in enhancing income and reducing post-harvest losses.

Importance of dry fish production

Dry fish production holds significant socio-economic and nutritional importance, especially in coastal and inland fishing communities. It provides a practical method to preserve surplus catch, ensuring year-round availability of fish even in off-seasons (Dey et al., 2024). Dry fish is a rich source of protein, essential fatty acids, and minerals, making it a valuable component of diets in many regions (Kumar et al., 2024). From an economic perspective, dry fish processing offers employment and income opportunities for small-scale fishers, traders, and women engaged in post-harvest activities. It adds value to lower-grade or excess fish that might otherwise go to waste, reducing post-harvest losses (Kimani et al., 2022). Additionally, dry fish has strong market demand both domestically and internationally, contributing to trade and local livelihoods. In regions lacking cold storage or modern preservation facilities, dry fish production remains a cost-effective and accessible method to support food security, nutrition, and community resilience.

Traditional drying methods and limitations

In many fishing communities, the most common method for preserving fish is open sun drying. This involves spreading cleaned fish on mats, sand, rocks, or raised platforms out directly to sunlight and air. While this method is simple, low-cost, and widely practiced, it presents several challenges:

Weather dependence: Open sun drying trusts entirely on favourable weather. Rain, high humidity, or sudden weather changes can disrupt the drying process, leading to spoilage.

Contamination risks: Fish dried in the open is unprotected to dust, insects, birds, animals, and other contaminants, affecting both hygiene and quality.

Uneven drying: Inconsistent sun coverage and airflow can result in uneven moisture removal, increasing the risk of mold, bacterial growth, or inferior product quality.

Nutrient loss: Prolonged and uncontrolled exposure to sunlight can degrade certain nutrients, reducing the nutritional value of the dried fish.

Limited scalability: Traditional drying methods may not meet larger market demands due to space constraints, time requirements, and product quality issues.

Overview of solar tunnel dryers

Solar tunnel dryers are semi-cylindrical and greenhouse-type structures designed to dry agricultural and fishery products using solar energy in a controlled and protected environment. In dry fish production, these dryers offer a hygienic and efficient alternative to traditional open sun drying methods. A typical solar tunnel dryer consists of a metal or bamboo frame covered with UV-stabilized transparent polyethylene or polycarbonate sheets. The structure traps solar heat, raising the internal temperature and creating a steady airflow that helps remove moisture from fish evenly and quickly. Mesh trays or racks are placed inside to hold the fish, allowing better exposure to warm air from all sides.

Working principle

- **Solar radiation capture:** Sunlight passes through the transparent cover, heating the air inside the tunnel.
- **Heat retention:** The enclosed structure retains heat, increasing the internal temperature and lowering relative humidity.
- **Air circulation:** Natural convection or small fans (in some models) help circulate hot air over the fish placed on mesh trays or racks.
- **Moisture evaporation:** The warm, dry air absorbs moisture from the fish, which is then expelled through air outlets or ventilation openings.
- **Controlled drying:** The process ensures uniform, faster drying compared to open sun drying, while protecting fish from contamination.

Design and Components

Structure and Materials

- **Frame:** The primary structure is often made from galvanized iron (GI) pipes, aluminium, or treated bamboo. These materials provide durability, corrosion resistance, and strength to withstand wind and weather.
- **Covering material**: Transparent UV-stabilized polyethylene or polycarbonate sheets cover the frame. This material allows sunlight to enter while retaining heat inside, acting like a greenhouse.
- **Drying trays or racks:** Fish are placed on mesh or perforated trays, usually made from food-grade plastic, stainless steel, or galvanized wire mesh. These trays allow air circulation from all sides.
- **Flooring:** Floors are often made of concrete, brick, or compacted earth to prevent dust and pests from entering the drying area.
- **Air inlets and outlets:** Solar tunnel dryers are equipped with strategically placed vents or openings to allow fresh air to enter and moist air to exit. This help maintain airflow without requiring electrical power.

- **Natural convection:** The heat difference between the bottom and top parts of the dryer creates a natural upward airflow, removing moisture from the fish.
- **Forced convection:** In some models, solar-powered or electric fans are installed to enhance airflow and drying uniformity and it is used in larger dryers.
- **Solar heat regulation:** The transparent cover traps solar energy, raising internal temperatures to between 40–70°C, ideal for drying fish without cooking or burning it.
- **Adjustable vents:** Vents can be opened or closed to regulate internal temperature and humidity levels as required.
- **Moisture balance:** Effective control ensures that fish dries uniformly, preserving quality, colour, and nutritional value while preventing under- or over-drying.

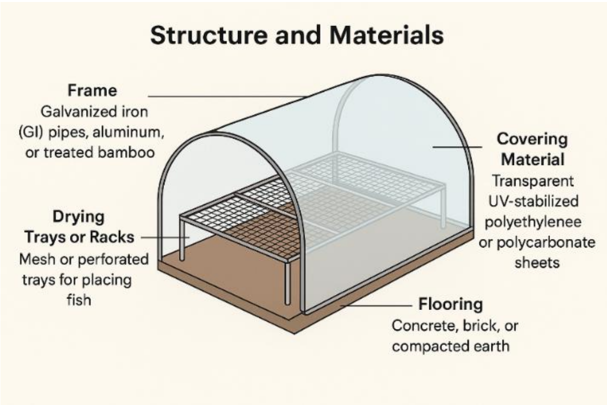

Fig 1. Structure of solar tunnel dryer

Fig 2. Outdoor setup of solar tunnel dryer

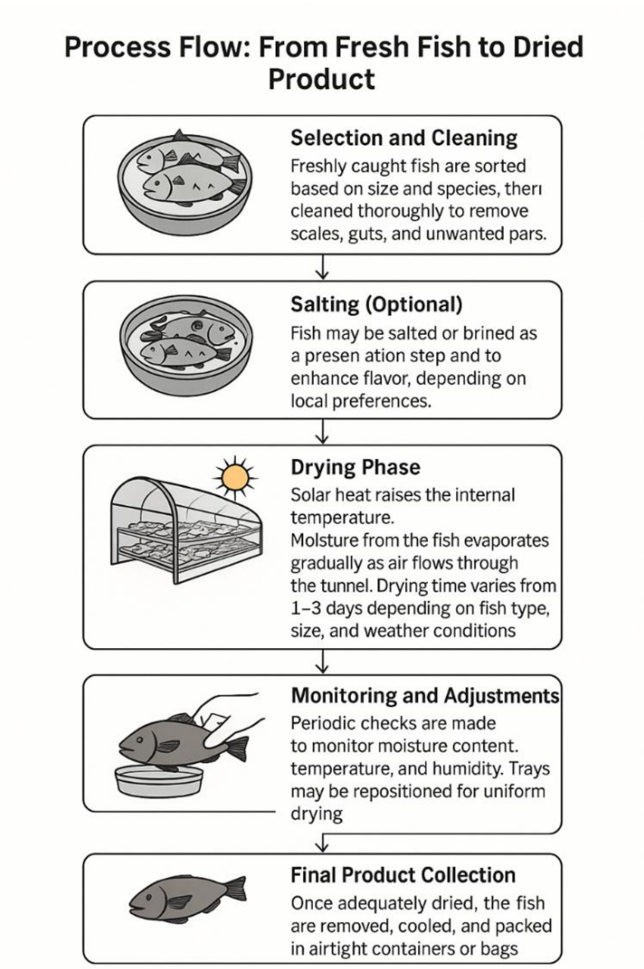

Fig 3. Process of dry fish making

Pros of solar tunnel dryer for dry fish production:

a) **Improved drying efficiency and quality**: This method provides faster and more uniform drying compared to open sun drying, and the reduced moisture content ensures better product quality in terms of colour, texture, and nutritional value.

b) **Hygienic drying environment:** The dryer protects drying fish from external contamination risks such as dust, insects, and animals. The tunnel solar dryer meets food safety standards.

c) **Energy-efficient and eco-Friendly**: This method utilizes renewable solar energy and requiring no fuel or electricity for basic operation.
d) **Reduced post-harvest losses:** This drying method helps reduce spoilage and waste by preventing fungal and bacterial growth during the drying process.
e) **Cost-effective:** Though initial investment is higher, long-term savings are achieved through lower operating costs and reduced product loss.
f) Scalability and Flexibility: It is suitable for both small-scale and medium-scale fish processors and can be customized in size according to production needs.

Cons of solar tunnel dryer for dry fish production:

a) **Initial investment cost**: It has a higher setup and construction cost compared to traditional drying methods.
b) **Space requirement**: It requires a dedicated area for installation, which may not be available in closely populated fishing communities.
c) Weather dependence: While it performs better than open drying, continuous cloudy or rainy days can still reduce its efficiency, especially in non-hybrid model**s.**
d) **Capacity limitation:** It may not handle very large-scale production unless specifically designed for that capacity.
e) Immediate health risks for dry fish makers: If workers stay inside a solar tunnel dryer while working in 40–50°C heat, it can pose health risks due to heat exposure, including symptoms such as heat exhaustion, heat stroke, and dehydration.
f) **Training and maintenance needs**: It requires basic training to operate effectively, including monitoring temperature, humidity, and airflow. Occasional maintenance of the structure and materials, such as replacing UV plastic covers, is also necessary.

Conclusions

Solar tunnel dryers are an efficient and sustainable solution for dry fish production. This method improvs product quality, reducing contamination risks, and lowering dependence on weather conditions. While the technology presents clear advantages such as energy savings and enhanced hygiene, it also poses challenges like higher initial investment, limited capacity for large-scale operations, and potential heat-related health risks for workers. Therefore, careful planning, proper design, and safety measures can help balance these pros and cons, making solar tunnel dryers a viable option for improving traditional fish drying methods.

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Article ID : 05/VIII/41/0825

THE SILENT DESTROYER : SQUIRREL INFESTATION THREATENS COCONUT CULTIVATION IN ASSAM

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Abstract
Coconut cultivation in Assam is increasingly threatened by the Hoary-bellied Himalayan Squirrel (*Callosciurus pygerythrus*), a vertebrate pest that has become highly destructive in homestead gardens. This study presents findings from field surveys conducted across three major coconut-growing districts— Kamrup (R), Nagaon and Nalbari—where significant crop losses and palm cutting were reported. Farmers rely on traditional deterrents, though integrated pest management approaches are urgently needed. This article documents the extent of the threat and explores possible mitigation strategies.

Keywords: Coconut cultivation, Hoary-bellied Himalayan (HBH) Squirrel, Vertebrate pest

Introduction

The sub-tropical climate of North-Eastern India provides congenial agro-climatic conditions conducive to the cultivation of plantation crops, including coconut. Over the past few decades, coconut cultivation has gradually expanded beyond traditional areas into non-traditional regions across various Northeastern states. The total area under coconut cultivation in the region was approximately 26.20 thousand hectares, with a total production of 208.15 million nuts during 2023–24 (Source: Ministry of Agriculture and Farmers Welfare). Assam is the major coconut producing state in N-E India with area coverage of 20.8 thousand ha. The major coconut growing districts are Kamrup, Nagoan, Barpeta, Nalbari, Baksa, Sonitpur and Golaghat.

Coconut (*Cocos nucifera* L.) is an exceptionally versatile crop that provides a wide range of essential resources for human life. It can be considered as a food crop, oil yielding crop, a fiber-yielding crop, a beverage crop, a timber yielding crop and fuel yielding crop. It has enormous health benefits. Coconut provides variety of raw materials with commercial importance. Although Assam's climate and soil are suitable for coconut cultivation, the crop is predominantly raised on small and marginal holdings as a homestead crop (Hebbar *et al*., 2024) or in sporadic manner in the residential campus. The people of Assam follow "Bari" plantation of the crop i.e. along with other crops like Areca nut and other fruit crops coconut is grown.

The Threat: Hoary-bellied Himalayan Squirrel

Amongst many constraints, major threat to coconut cultivation at present is the damage caused by a species of squirrel, named, The Hoary-bellied Himalayan Squirrel (Sc. Name: *Callosciurus pygerythrus,* family Sciuridae) was observed to prefer a diverse and resource-rich habitat which is predominantly composed of bamboo species (*Bambusa* spp., *Dendrocalamus* spp.), *Ficus* species, *Azadirachta indica*, *Bombax ceiba*, *Olea europaea* along with a variety of other fruit-bearing plants, wild shrubs and trees. It was reported that, it is a major pest of coconut in North East India (Kumawat *et al.,* 2016). Among the 13 animals identified as destructive in home gardens, the

Hoary-bellied Himalayan Squirrel (*Callosciurus pygerythrus*) was reported as the most damaging rodent pest, accounting for 15% of the cases (Yashmita-Ulman *et al*., 2020). Due to this problem the coconut growers are randomly cutting down the bearing coconut palm which is leading to reduced coconut production in the state.

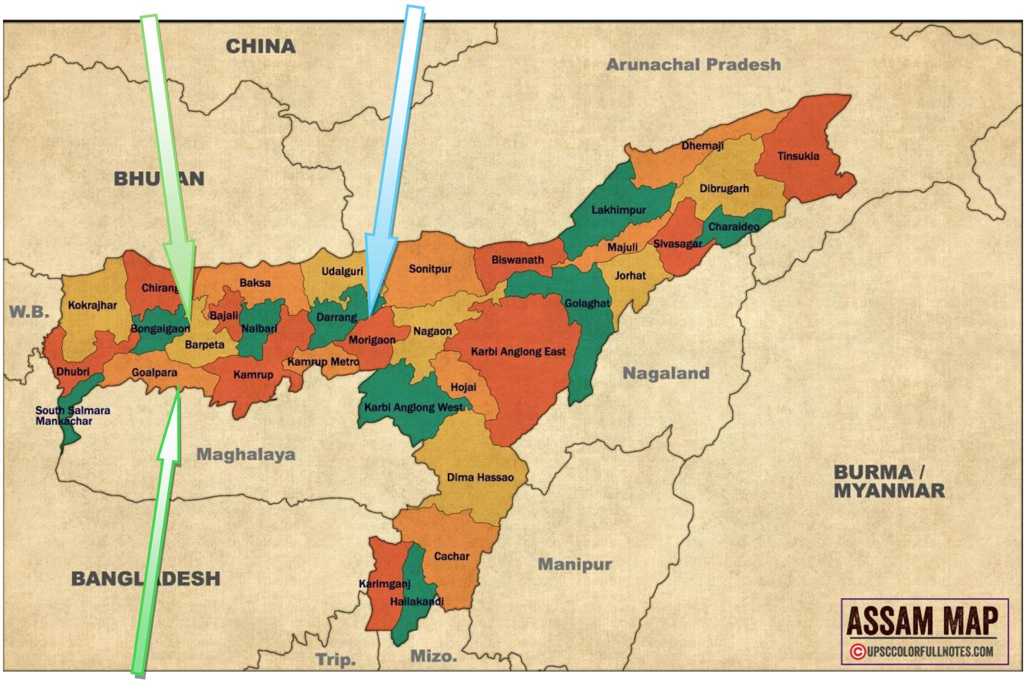
Reasons for Squirrel Attacks and Damage

Forest coverage depletion in the area is the primary reason for the emergence of squirrels and their increased attacks on homestead plants and crops. The practice of 'Bari' plantation may be one of the reasons for squirrel infestation in homestead plantation of coconut. Squirrels are active throughout the year but infestation is more in August, September and October month. Squirrel can damage both tender and mature coconut by making hole and cutting the nut and make nut unusable for consumption.

Photograph 1. Hoary-bellied Himalayan Squirrel and coconut damage in farmer's field, Hajo, Kamrup district.

Study Area

Three districts of Assam like – Kamrup (R), Nagaon and Nalbari located on the Lower Brahmaputra valley and Central Brahmaputra valley agro climatic zone were selected for the study of squirrel attack on coconut palms in Assam. The three selected districts are major coconut growing district of Assam covering around 24.68% of total coconut areas of the state. Homestead plantation of coconut at Niz Hajo, Satdala, Suwalkuchi, Ramdia, Ujankuri, Chandkuchi, Deodhar was selected for studying the squirrel infestation.



Methodology

A questionnaire survey was conducted during the month from March to June'2023 in the selected study areas. Total 99 farming household were taken for survey randomly in different villages of 3 districts. All these 99 respondents interviewed were the ones who are related with Coconut Development Board. All the respondents were well aware of the particular species of squirrel causing destruction and the type of destruction caused. They were questioned about the numbers of present and past palm population, numbers of cutting palm, nut reduction etc. They were also questioned about technique used for preventing the infestation caused by the species.

Results

1. Farmers have cut down coconut palms on an average 1/4th i.e. 25% of their palms due to damage, specially caused by HBH squirrel.
2. Highest cutting of coconut palms has been observed in certain parts of Hazo block of Kamrup district which went up to 43%. Cutting was minimum at Nalbari (22.97%).
3. Nut reduction was observed at the range of 22 to 66%, on an average 47%. This reduction is due to the damage majorly by HBH squirrel, followed by monkey and then diseases like stem bleeding and bud rot.
4. It was observed that close planting of coconut (less than 10ft) was mostly affected by HBH squirrel damage.

Discussion

The study found that the squirrel was the most destructive vertebrate pest in home gardens. Squirrel was recorded as topmost destructive animal in home gardens. The squirrels were notorious for damaging the cash crop yields of Areca nut, Coconut, Pepper vines *etc*. Conover & Chasko 1985 in Kansas, USA observed that 56% of the farmers reported that the losses incurred due to wildlife were higher than they were willing to tolerate.

In the current study, it has been reported that the squirrel cut the coconut inflorescences at the early stage and it also makes hole on tender coconut, making the nut unusable for consumption.

Squirrel can damage both tender and mature coconut, sometimes also on the trunks and on inflorescences, opening ways for disease or insect attacks. Mature nuts are fed on when they have fallen to the ground.

Observations

It was observed that huge loss in production has occurred due to attack of squirrel at early stage of nut bearing. Around 23-53% of palms have been felled down by the farmers due to squirrel attack in last three years which lead to yield reduction of coconut of around 22 to 66 % per palm per year.

Results were found in the present study where it was observed that villagers created noise by striking bamboo poles against palm trunks for scattering the squirrel. In some places villager made reflection by using mirror to chase away the squirrel. In some places it was observed to use of mechanical barrier like tin plating for controlling squirrel infestation. Some people either tolerated the animals or tried to scare off the squirrel species to protect their crops.

Conclusion & Recommendations

Squirrel infestation, by *C. pygerythrus*, is emerging as a serious challenge to coconut production in Assam. Integrated pest management, including mechanical, ecological and awareness-based strategies, must be adopted. Reforestation and habitat management could also reduce pressure on homestead plantations. Further research and inter-agency cooperation are necessary to address this overlooked issue.

Photograph 2. Mechanical barrier with GI sheet at Bagta, Hajo

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Article ID : 05/VIII/42/0825

SUNFLOWERS AND SCIENCE: WHY FATTY ACIDS MAKE THIS FLOWER A SUPERSTAR

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Abstract

Sunflowers, with their radiant blooms, are more than just a feast for the eyes—they're a nutritional and environmental powerhouse. This article explores the science behind the fatty acids in sunflower seeds and oil, particularly linoleic and oleic acids, which support heart health, skin vitality, and overall wellness. Backed by research, we uncover how these compounds lower cholesterol, reduce inflammation, and enhance daily diets through versatile uses like cooking and skincare. From simple recipes to eco-friendly farming, sunflowers shine as a sustainable choice that benefits both people and the planet. Complete with practical tips, a comparison table, and a seed diagram, this article reveals why sunflowers are a true superstar, inviting readers to embrace their health and environmental potential.

Introduction

Picture a golden field of sunflowers, their bright petals stretching toward the sky like nature's own solar panels. These iconic blooms, immortalized in Van Gogh's paintings and cherished in gardens worldwide, are more than just a pretty face. Sunflowers (*Helianthus annuus*) hold a secret weapon in their seeds and oil: fatty acids, the unsung heroes of nutrition. These compounds, essential for our health, make sunflowers a superstar in both science and everyday life.

Their towering stems and cheerful faces symbolize joy and resilience, brightening everything from rural landscapes to urban balconies. But beyond their beauty, sunflowers are a nutritional powerhouse. Their seeds and oil are packed with fatty acids—fats that fuel our bodies, protect our hearts, and even keep our skin glowing. Did you know that a handful of sunflower seeds or a drizzle of their oil can transform your diet? This article dives into the science behind these fatty acids, revealing how they benefit your health, how to incorporate them into your life, and why sunflowers are a win for the planet. Get ready to see sunflowers in a whole new light—not just as a flower, but as a key to wellness and sustainability.

What Are Fatty Acids and Why Do They Matter

If you've ever wondered what makes certain foods "healthy fats," the answer lies in fatty acids—the building blocks of fats that our bodies need to thrive. Think of them as tiny powerhouses that fuel your cells, build strong membranes, and even help produce hormones. Fatty acids come in three main types: saturated (found in butter), monounsaturated (like in olive oil), and polyunsaturated, which includes omega-3s and omega-6s. The omega-6 fatty acids, such as linoleic acid, are especially important because our bodies can't make them—we have to get them from food.

Why should you care? Omega-6 fatty acids, when consumed in balance, are superstars for your health. They help lower "bad" cholesterol (LDL), reducing the risk of heart disease. They support brain function, keeping your mind sharp, and they play a role in controlling inflammation, which can protect against chronic conditions. However, balance is key. Too much omega-6 without enough omega-3s (found in fish or flaxseeds) can tip the scales toward inflammation. The good news? A varied diet with smart choices like sunflower seeds or oil keeps things in check.

Sunflowers shine here because they're rich in linoleic acid, a key omega-6, and oleic acid, a monounsaturated fat with its own health perks. Whether you're munching on seeds or cooking with sunflower oil, you're tapping into a natural source of these essential nutrients. Let's explore what makes sunflowers such a standout in the world of fatty acids.

Sunflowers: A Fatty Acid Powerhouse

When it comes to fatty acids, sunflowers are in a league of their own. Their seeds and oil are loaded with linoleic acid, an omega-6 fatty acid that makes up 55–70% of standard sunflower oil, and oleic acid, a monounsaturated fat that dominates in high-oleic varieties (up to 80%). These compounds give sunflowers their nutritional edge, whether you're sprinkling seeds on a salad or cooking with their oil.

To put this in perspective, let's compare sunflower oil to other popular oils. Olive oil is famed for its monounsaturated fats (70% oleic acid), but standard sunflower oil beats it for omega-6 content, making it a heart-health champion. Canola oil is balanced but less rich in linoleic acid, while soybean oil often contains more saturated fats. High-oleic sunflower oil, developed through selective breeding, rivals olive oil for stability in high-heat cooking, with a longer shelf life to boot. This versatility makes sunflower oil a kitchen staple worldwide.

The table below breaks down the fatty acid profiles of standard and high-oleic sunflower oil, showing their distinct strengths:

Fatty Acid	Standard Sunflower Oil (%)	High-Oleic Sunflower Oil (%)
Linoleic Acid (Omega-6)	55–70	10–20
Oleic Acid (Monounsaturated)	15–35	75–85
Saturated Fats	8–12	8–10
Others	2–5	2–5

Table 1: Comparison of fatty acid profiles in standard and high-oleic sunflower oil, showcasing their nutritional diversity.

How do we get these fatty acids? Sunflower seeds are harvested, and their oil is extracted through cold-pressing (which preserves nutrients) or refining (more affordable but less nutrient-dense). The seeds themselves are a nutritional gem, packing not just fatty acids but also vitamin E, magnesium, and fiber. Beyond food, sunflower oil powers everything from cosmetics to biofuels, proving its versatility. Whether you're after health benefits or culinary flexibility, sunflowers deliver.

Health Benefits Backed by Science

The fatty acids in sunflowers aren't just hype—they're backed by science. Linoleic acid, the star of standard sunflower oil, is a proven ally for heart health. A 2017 meta-analysis in the *Journal of Nutrition* found that diets rich in linoleic acid lowered LDL cholesterol levels, reducing the risk of heart disease. This omega-6 fatty acid helps keep arteries clear by balancing cholesterol, making it a smart choice for anyone looking to protect their ticker.

High-oleic sunflower oil, with its high monounsaturated fat content, takes things further. A 2020 study in the *American Journal of Clinical Nutrition* showed that oleic acid can reduce inflammation and improve blood lipid profiles, offering another layer of heart protection. Unlike saturated fats, which can clog arteries, oleic acid keeps things flowing smoothly. It's no wonder high-oleic sunflower oil is a favorite for health-conscious cooks.

Beyond the heart, sunflower fatty acids work wonders for your skin. The seeds and oil are rich in vitamin E, a powerful antioxidant that pairs with fatty acids to protect skin cells from damage caused by sun exposure or aging. This is why sunflower oil is a staple in moisturizers and serums—it hydrates and fights oxidative stress. Emerging research even suggests linoleic acid may support brain health by aiding cell membrane function, though more studies are needed.

To understand where these benefits come from, take a look at the sunflower seed itself. The diagram below shows a cross-section of a seed, with the outer hull protecting the nutrient-rich kernel where fatty acids are stored:

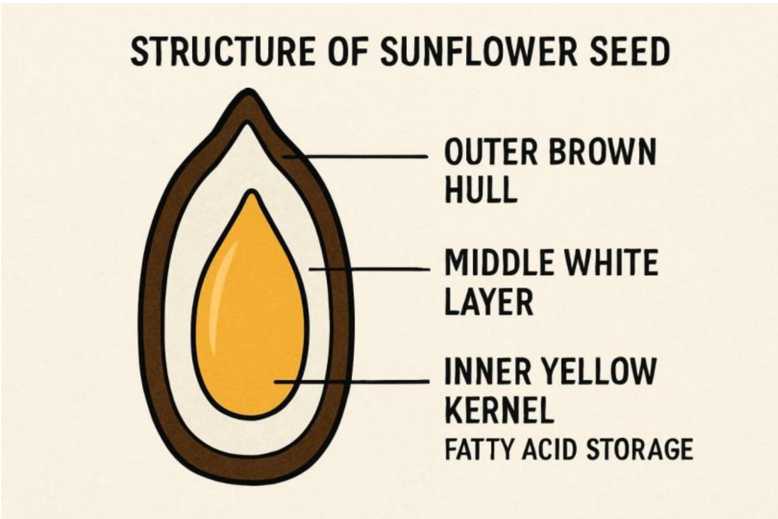

Diagram: Sunflower Seed Structure

- A simple illustration showing:
  - **Outer Hull**: A tough, protective layer (brown).
  - **Kernel**: The inner part where fatty acids like linoleic and oleic acids are stored in oil (yellow).
  - **Caption**: "Fatty acids like linoleic and oleic acids are concentrated in the kernel, ready to fuel your health."

One caveat: balance is key. Too much omega-6 without enough omega-3s (from foods like salmon or walnuts) can promote inflammation. But don't worry—a varied diet with sunflower seeds or oil alongside other nutrient-rich foods keeps things in harmony. With benefits for your heart, skin, and potentially your brain, sunflower fatty acids are a scientific slam dunk.

Sunflowers in Your Life: Practical Applications

Ready to bring sunflower power into your life? Sunflower seeds and oil are incredibly versatile, making it easy to tap into their fatty acid benefits. Start with the seeds: a quarter-cup delivers nearly half your daily vitamin E, plus a hearty dose of linoleic acid. Sprinkle them on salads, blend them into smoothies, or munch them straight from the bag for a nutrient-packed snack.

Sunflower oil is a kitchen MVP. Its mild flavor makes it perfect for salad dressings, while high-oleic versions shine in high-heat cooking like frying or roasting. Try this simple **sunflower seed pesto**: blend ½ cup roasted sunflower seeds, 2 cups fresh basil, 1 clove garlic, ¼ cup sunflower oil, and a pinch of salt. Spread it on toast or toss it with pasta for a nutty, nutritious twist. Or whip up a **sunflower oil vinaigrette**: mix 3 tablespoons sunflower oil, 1 tablespoon apple cider vinegar, 1 teaspoon mustard, and 1 teaspoon honey. Drizzle it over greens for a heart-healthy boost.

Beyond food, sunflower oil is a star in skincare. Its fatty acids and vitamin E hydrate and protect, making it a go-to in lotions and hair conditioners. Look for cold-pressed sunflower oil in cosmetics for maximum benefits. When shopping, choose organic seeds to avoid pesticides and cold-pressed oils for nutrient density. High-oleic oils are great for cooking, as they resist breaking down at high temperatures.

Don't be afraid to experiment! Swap butter for sunflower oil in baking, add seeds to granola, or try sunflower-based supplements for a concentrated dose of fatty acids. These small changes can make a big difference in your health, all while enjoying the sunny flavor of this versatile flower.

The Bigger Picture: Sunflowers and Sustainability

Sunflowers don't just nourish our bodies—they're good for the planet, too. Their deep roots anchor soil, preventing erosion and improving nutrient cycling, which makes them a farmer's friend. Unlike water-hungry crops like almonds, sunflowers are relatively low-maintenance, thriving in diverse climates with minimal pesticides. They also attract bees and other pollinators, supporting biodiversity and the food systems we all depend on.

Sunflower oil production is a sustainability win. Compared to palm oil, which drives deforestation, sunflower oil has a lighter environmental footprint. Its cultivation supports eco-friendly farming practices, ensuring we can enjoy its fatty acid benefits for generations. By choosing sunflower-based products, you're voting for a healthier planet while reaping the rewards of linoleic and oleic acids. It's a rare case where what's good for you is also good for the Earth.

Conclusion: Why Sunflowers Are a Superstar

Sunflowers are more than a cheerful bloom—they're a nutritional and environmental superstar, thanks to their fatty acids. Linoleic acid boosts heart health, oleic acid fights inflammation, and vitamin E keeps your skin glowing. From a handful of seeds to a drizzle of oil, sunflowers make it easy to add these benefits to your life. Whether you're tossing them in a salad, cooking up a storm, or slathering on a sunflower-infused moisturizer, you're tapping into science-backed wellness.

But the sunflower's brilliance doesn't stop at your plate or medicine cabinet. Its sustainable roots—literally and figuratively—support healthier soils and happier pollinators, making it a champion for the planet. Next time you see a sunflower swaying in the breeze, think of its hidden power. Try a new recipe, pick up a bottle of cold-pressed sunflower oil, or plant a sunflower in your garden to bring its magic home. Sunflowers don't just brighten fields—they brighten your health and the Earth's future.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/43/0825

TECHNIQUES OF RELEASING NATURAL ENEMIES AND THEIR RECOVERY EVALUATION

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Abstract

The effectiveness of biological control in integrated pest management (IPM) depends on the proper release and evaluation of natural enemies such as predators, parasitoids and pathogens. Release techniques are generally categorized into inoculative (small, periodic releases for long-term control) and inundative (mass releases for immediate suppression) which focus on enhancing existing populations. The most important factors influencing success is the selection of particular natural enemy and its approach in utilisation. Evaluating recovery and impact of released agents is critical to measure their establishment and efficacy. Direct evaluation methods include visual counts, sweep netting, and mark–release–recapture, while indirect methods assess parasitism or predation rates and may involve molecular tools like Polymerase Chain Reaction. These approaches help quantify agent dispersal, survival, and pest suppression. Recent advances such as statistical models support more precise monitoring and evaluation. Overall, effective release strategies and robust recovery evaluation are essential for optimizing biological control, minimizing chemical use, and ensuring sustainable pest management. Integration of ecological understanding with modern technologies enhances the reliability and success of natural enemy-based interventions.

Keywords: Biological control, Natural enemies, Survivorship, Predators, Parasitoids

Introduction to Natural Enemies

Natural enemies are organisms that play a crucial role in regulating populations of other organisms. They achieve this by directly killing their prey or hosts, reducing their reproductive capacity, or otherwise causing them harm. Natural enemies can be broadly classified into two main categories: macrobial and microbial agents. Macrobial natural enemies include predators and parasitoids, while microbial natural enemies consist of pathogens. Understanding and utilizing natural enemies is a key component of biological control strategies in agriculture and ecology.

Biological Control Strategies

1. Classical Biological Control

This approach involves the introduction of exotic, co-evolved biological control agents for long-term pest management. It includes the following steps:

- Identification of target pests
- Foreign exploration for suitable natural enemies
- Importation and quarantine testing
- Mass release and evaluation

Classical biological control has been successfully employed for various invasive pests, such as *Rodolia cardinalis* for controlling *Icerya purchasi*.

Table 1: Important Invasive Insect Pests in India (Gupta *et al.*, 2019).

Common Name	Scientific Name	Year of Introduction
Woolly apple aphid	*Eriosoma lanigerum* (Hausmann)	1889
San Jose scale	*Quadraspidiotus perniciousus* (Comstock)	1911
Lantana bug	*Orthezia insignis* Browne	1915
Cottony cushion scale	*Icerya purchasi* Maskell	1921
Potato tuber moth	*Phthorimaea operculella* (Zeller)	1937
Diamond back moth	*Plutella xylostella* (Linn.)	1914
Pine woolly aphid	*Pineus pini* (Macquart)	1970
Subabul psyllid	*Heteropsylla cubana* Crawford	1988
Serpentine leaf miner	*Liriomyza trifolii* (Burgess)	1990
Coffee berry borer	*Hypothenemus hampei* (Ferrari)	1990
Spiraling whitefly	*Aleurodicus disperses* Russell	1993
Silver leaf whitefly	*Bemisia argentifolii* Bellows	1999
Blue gum chalcid	*Leptocybe invasa* Fisher & La Salle	2006
The coconut eriophid mite	*Aceria gurreronis* Keifer	1997
Papaya mealy bug	*Paracoccus marginatus* Williams & Granara de Willink	2005
Cotton mealy bug	*Phenococcus solenopsis* Tinsley	2006
Erythrina gall wasp	*Quadrastichus erythrinae* Kim	2005
South American tomato leaf miner	*Tuta absoluta* Meyrick	2014
Fall armyworm	*Spodoperda frugiperda* (J.E. Smith)	2018

2. Augmentation Strategies

Augmentation involves periodic release of natural enemies to enhance their population and effectiveness. **DeBach (1974)** classified augmentation into four techniques:

- Inoculative Release: Small numbers of natural enemies are introduced to establish a long-term population.
- Inundative Release: Large-scale releases provide immediate but short-term pest suppression.
- Accretive Release: Small numbers of natural enemies are introduced periodically.
- Supplementary Release: Released when pests escape natural enemy control.

3. Conservation Biological Control

This strategy focuses on enhancing natural enemy populations by avoiding harmful practices and promoting favourable conditions. Methods include:

- Reducing pesticide use
- Providing alternative food sources and shelters
- Improving habitat quality

Recovery Evaluation of Natural Enemies

Assessing the impact of released natural enemies involves various techniques:

1. **Monitoring :** Regular field surveys are conducted to observe changes in natural enemy and pest populations.
2. **Mark-Recapture Method :** Individuals are captured, marked, released, and recaptured to estimate survival and dispersal rates.
3. **DNA Analysis :** Genetic tools are used to trace the origin and effectiveness of introduced natural enemies. Tools like Polymerase Chain Reaction (PCR) are used for analysis.

Techniques for measuring effectiveness of natural enemies

1. Correlation of pest and natural enemy abundance

- ✓ To correlate the damage exerted by the pest, or the crop yield, with natural enemy populations.
- ✓ High natural enemy populations correlated with low damage levels or high crop yields
- ✓ If natural enemies are highly mobile, such comparisons may be possible only for a very short period of time.
- ✓ The correlation method relies largely on life- table and density data for pests and their natural enemies and attempts to show a cause and relationship between an increase in natural enemies and decrease in the pest(s) or vice-versa.
- ✓ The major deficiencies are the lack of any check on control, the impossibility of demonstration when the natural enemy is not efficient that the host has a chance to increase only at low host densities and the impossibility of demonstrating control when the natural enemy is so efficient that the host ‘’ never’’ has a chance to increase.

2. Natural enemy exclusion (experimental) method

- ✓ The use of experimental techniques in demonstrating the regulatory ability of natural enemies has been clearly successful in many cases, which are then compared to other cases in which such methods have not been used.
- ✓ It has been most effective against pests having limited mobility and producing many generations per year.
- ✓ Most of these methods can be employed with either newly introduced, exotic natural enemies or indigenous natural enemies. These includes-

i) Addition Method : This is essentially a ‘’before’’ and ‘’after’’ comparison. We set up a number of plots and introduce natural enemies into the selected plots and leave others as controls. Plots must be set up prior to introductions of natural enemies and must be distant from each other.

ii) Exclusion Method :

- ✓ This technique involves the elimination and subsequent exclusion of resident natural enemies.
- ✓ Significantly different “before and after ‘’ pest population densities indicating different equilibrium levels for the two groups of plots serve as a direct measure of the control and regulating effectiveness of the natural enemies.
- ✓ Experiments must be designed to be biologically realistic.
- ✓ The technique works best with insects with low powers of dispersal.
- ✓ Natural enemies are mechanically excluded from hosts by use of exclusion cages (Paired cage technique). These take several different forms.
- ✓ The general process is as follows –
    - o Select sites for the studies.
    - o Clean up sites with insecticides or by hand removal.
    - o Re-introduce pests into cages.
    - o Close cages up and let pests become established.
    - o Open one cage up to natural enemies.
    - o Take census counts during the study.

iii) Interference Method :

- ✓ This method involves greatly reducing the efficiency of natural enemies in one set of plots as contrasted to another set having natural enemies undisturbed.
- ✓ Any increase in pest density in the interference plots, relative to the normal biological control plots, demonstrates the effectiveness of the natural enemies.
- ✓ The percentage parasitism may commonly be as great in the interference plots as in the normal activity plots.
- ✓ The density of the pest population at equilibrium is determined by the rate at which premature mortality of a pest increases with pest density.
- ✓ If the rate of parasitisation increases rapidly as the host population starts to increase, the host equilibrium density will be low.
- ✓ If it increases slowly, the density will be high because the equilibrium mortality level (mortality = natality) is reached quickly at low levels in the unexcluded plots.
- ✓ The various techniques in the Interference Method includes:
    1. **Insecticide Check Method** - Selective toxic materials are used to interfere with the natural enemies. Usually these are insecticides such as DDVP, Furadon or Carbaryl. They can also be substances such as talc or road dust. However, some compounds induce the condition of "hormoligosis".
    2. **Hand – Removal Method -** Natural enemies are periodically removed from area. Intensive labour required and time consuming and it is used in studies on regulation of spider mite densities by natural enemies on foliage of strawberries and papaya. It is also too expensive with respect to "manpower."
    3. **Biological Check Method**
        - Interference with ants that naturally interfere with natural enemies to attack honeydew producing insects.
        - Ants may be eliminated by insecticides (e.g. Amdro)
        - Restriction of the Argentine ant, *Iridomyrmex humilis* Mayr, resulted in control of California red scale. In Hawaii, suppression of the big-headed ant, *Pheidole megacephala*, in pineapple plantings led to reductions in pineapple mealybug densities.
    4. **Trap Method**
        - A large area is selected as the test site.
        - Insecticides are applied around the outside borders thus creating a wide band of insecticide treated foliage which must be crossed by organisms either leaving or entering the test site.
        - Nothing is modified directly in the test area; thus, natural enemies are not inhibited.
        - This technique is most successful with fairly sessile pests which have rather mobile natural enemies.
        - By use of several different selective chemicals applied at required intervals one could make this a fairly sophisticated technique.

3. Mathematical modelling of population processes

- ✓ The advent of computers that can swiftly handle tremendous amounts of data has led to the development of biological systems models which can be used for management and evaluation.

- ✓ These models, with the adequate input of biological and environment and environmental parameters from the field, are designed to make it possible to evaluate a current situation, predict what is likely to happen given certain conditions, and recommend procedures to obtain a desired result.
- ✓ However, the natural enemy subcomponents for these models are poorly developed.
- ✓ The development of realistic, reliable models is likely to be slow and expensive.
- ✓ Experimental approaches are probably still best for demonstrating the effects of natural enemies, but they have little predictive or management value by themselves.
- ✓ Hence, the development of better systems models will continue, although relatively simple models, such as those used for the management of olive pests by chemical, cultural, and biological methods have been effective.
- ✓ Management options can be investigated by the manipulation of parameters in computer-based models.

Conclusion

Biological control is a sustainable pest management approach offering long-term benefits with minimal environmental impact. Its integration into IPM strategies can significantly reduce reliance on chemical pesticides and promote ecological balance. Various releasing techniques like augmentative biocontrol has long been recognized as a promising pest control alternative to conventional pesticide use. Also, there is a need to understand various recovery evaluations to follow up the practices that we have been carrying out. Overall, biological control creates opportunities for the local population, small- and large-scale farmers. Continued refinement and adaptation of biological control approaches and applications are necessary. In recent years many small and large entrepreneurs have entered into the commercial production of biopesticides resulting in the entry of various biopesticides products into the Indian market, Commercialisation of biocontrol products is a multi-step process involving a wide range of activities (1) Isolation of micro-organism from the natural ecosystem; (2) Evaluation of bio agent both *in vitro* and under glass house conditions, (3) Testing of the best isolate under field conditions: (4) Mass production (5) Formulation (6) Delivery: (7) Compatibility, and (6) Registration and release. There are 41 commercially available biopesticides formulation India which are produced by different companies as well as government institutions (Hedge and Vijaykumar, 2022). It is also shown that there are 970 registered biopesticides in India in different formulations under section 9(3) and 9(3B) in CIBRC, India (CIBRC, 2025).

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/44/0825

THE GENUS *Berberis*: AN EXPLORATION OF CYTOLOGICAL AND ETHNOBOTANICAL ASPECTS

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Abstract

A rich source of traditional medicine, the *Berberis* genus has been widely used in various cultures for its therapeutic properties. The genus *Berberis* with more than 500 species distributed in temperate and subtropical regions is of vital importance in both cytological and ethnobotanical research. This study presents a comprehensive exploration of the cytological and ethnobotanical characteristics of *Berberis* species. Cytological investigations reveal considerable diversity in the numbers and structures of chromosomes, which contributes to taxonomic complexity and provides insights into evolutionary relationships within lineages. In addition, *Berberis* has long been respected in traditional medicine systems for its wide range of therapeutic applications, including antimicrobial, anti-inflammatory, and ant diabetic properties, primarily attributed to its bioactive alkaloids such as berberine. By integrating cytogenetic data with ethnobotanical insights, this study emphasizes the biological diversity, medicinal potential of the genus and the need for its conservation and sustainable use.

Key words: Cytology, Ethnobotany and *Berberis*

Introduction

The genus *Berberis* is a member of the family Berberidaceae, which includes a diverse range of wild medicinal plants of vital importance. The genus *Berberis*, commonly known as barberry, includes about 500 species found mainly in temperate and subtropical regions of Europe, Asia, Africa, and the Americas (Ahrendt 1961). In India, the genus *Berberis* is represented by 55 species (Rao et al., 1998). Taxonomically, *Berberis* is a complex genus exhibiting variable characteristics among its species, which are typically characterized by deciduous or evergreen shrubs with thorny yellow stems, simple leaves, and sepals arranged in two whorls. Various *Berberis* species are valued for their ethnobotanical properties, with root extracts of *B. asiatica, B. lyceum*, and *B. chitrea* being used to treat a number of ailments including diarrhea, constipation, piles and cough, as well as acting as an antiseptic, intestinal astringent, and blood.

Cytological studies of Genus *Berberis*

Cytological studies have revealed that *Berberis* species exhibit different numbers of chromosomes, ranging from 2n = 14 to 2n = 56. This variation in the number of chromosomes indicates that polyploidy has played an important role in the evolution of the genus. Cytological studies have also revealed the presence of diverse cellular structures and metabolites, which contribute to the medicinal properties of *Berberis*. A comprehensive review of cytological literature reveals that 110 species/cytotypes of *Berberis*, including 15 species from India, have been cytologically investigated, exhibiting chromosome numbers of 2n = 28 (90.90%), 2n = 42 (1.82%), or 2n = 56 (7.27%). The genus *Berberis* is monobasic, with a base chromosome number of x = 14. Notably, polyploidy is observed in 8.18% of the species, which is higher than the 6% reported by Hong (1990) for species with only diploids known from India.

Cytological anomalies observed in *Berberis* species, such as cytomixis, chromosomal stickiness, Un- oriented bivalents, laggards, and bridges, may have important implications for genetic diversity and evolution.

Cytomixis: The transfer of chromatin between cells can lead to genetic variations and increased diversity.

Chromosomal stickiness: Abnormal chromosome behavior can result in chromosomal rearrangements and mutations.

Un-oriented bivalents: Disrupted meiotic processes can lead to reduced fertility and increased genetic variation.

Laggards: Delayed chromosome movement during meiosis can cause genetic abnormalities and variations.

Bridges: Chromosomal breakage and fusion can result in structural chromosomal changes.

These anomalies can contribute to the generation of genetic diversity, which is essential for adaptation, evolution, speciation, potentially leading to the formation of new species. The presence of intraspecific genetic diversity in *Berberis* species can have significant implications for their evolution, adaptation, and survival.

Flowers of *B. asiatica*

Flowers of B. lyceum

Inflorescence of *Berberis spp.*

Ripe Seeds of Berberis spp

Wood of Berberis spp.

Genetic diversity is crucial for plant species like *Berberis*, enabling adaptation to changing environments and evolution over time. High genetic diversity helps species survive environmental changes, such as climate change, by providing traits that promote survival and thrival. Genetic diversity can provide a buffer against disease and pest outbreaks, as some individuals may possess traits that make them more resistant. Preserving genetic diversity is essential for the long-term conservation of plant species, as it allows them to adapt and evolve in response to changing conditions.

Ethnobotanical Significance

Berberis species have been widely used in traditional Indian medicine, particularly in Ayurveda, for various purposes. Here are some of the ethnobotanical uses of *Berberis* species in India:

Medicinal Properties

Digestive Health: *Berberis aristata*, also known as Indian Barberry, is indeed known for its digestive benefits, including stimulating digestion, improving appetite and relieving digestive discomforts.

Antimicrobial and Anti-inflammatory *Berberis* species contain the bioactive alkaloid berberine, which possesses notable antimicrobial and anti-inflammatory properties, rendering it useful for treating infections and inflammatory conditions.

Antidiabetic: *Berberis lycium* and *Berberis aristata* have been traditionally employed in the management of diabetes due to their hypoglycemic properties, attributed to the presence of berberine, which helps regulate blood sugar levels and improve insulin sensitivity.

Cardiovascular Health: *Berberis* species are believed to help regulate blood pressure and cholesterol levels, supporting cardiovascular health.

Therapeutic Uses

Skin Conditions: *Berberis* species are used to treat various skin conditions, including acne, eczema, and wounds, due to their antimicrobial and anti-inflammatory properties.

Eye Health: *Berberis aristata* are thought to support eye health by soothing irritations and promoting overall visual wellness.

Respiratory Disorders: *Berberis lycium* species have been used traditionally to relieve respiratory problems such as cough, bronchitis and throat infections.

Urinary Tract Health: *Berberis* species are believed to have diuretic properties, making them beneficial for urinary tract health and conditions like urinary tract infections. It can also used in Joint inflammation.

Traditional Remedies

Wound Healing: *Berberis vulgaris* are used to promote wound healing due to their antimicrobial and anti-inflammatory properties. A decoction of the roots is prepared, thickened, allowed to cool and applied twice a day to heal wounds (Rani et al. 2013).

Diabetes and jaundice: The fresh roots of *Berberis ceratophylla* are cut into small pieces and a decoction is prepared. It is later filtered and thickened, dried in the shade and made into small tablets. For adults, 3 tablets a day are recommended along with bitter gourd juice to treat diabetes. These tablets are also taken with kujja mishri (local sweet made of sugar) and water to treat jaundice (Rani et al. 2013).

Menstrual Disorders: *Berberis* species are sometimes included in Ayurvedic preparations to help regulate menstrual cycles and address associated discomforts.

Acidity and piles: Fresh/dried flowers of *Berberis asiatica* (Commonly called as Chunchri) are boiled in water and strained. The extract is taken in small doses with water cures piles.

Conclusion

The genus *Berberis* represents a diverse and medicinally significant group of plants with a rich history of ethnobotanical use across various cultures. From traditional applications in treating ailments such as eye irritation, respiratory infections, and digestive issues, to the modern recognition of its bioactive compounds like berberine, *Berberis* continues to hold therapeutic promise. Taxonomically, the genus encompasses a wide array of species with complex classification challenges, often due to morphological variability and hybridization. Cytological studies further enhance our understanding of the genus by shedding light on its genetic diversity and evolutionary relationships.

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ISSN : 2583-0910
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/45/0825

THE FATE OF BASMATI RICE IN CHANGING CLIMATE

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Abstract
The climate we face today differs significantly from that of 8000 years ago when basmati rice was first cultivated in northern India. The Basmati rice, esteemed for its distinctive aroma, elongated grains, and superior culinary qualities, is a vital crop in India. Beyond its culinary appeal, Basmati rice holds significant economic importance, contributing billions to India's export revenues and supporting the livelihoods of millions of farmers. However, the shifting climate during its growing season is making the cultivation of this export-potential crop challenging. These environmental pressures threaten not only the yield and quality of Basmati rice but also the socio-economic stability of the regions where it is grown, underscoring the urgent need for adaptive strategies to safeguard its future. This article emphasises the importance of preserving Basmati's unique traits to enhance yield and global competitiveness, ensuring its enduring legacy in both domestic and international markets in changing climatic conditions.

Keywords: Basmati Rice, Climate change, Economic demand, Crop resilience

Climate Change: A looming threat
The changing climatic trends not only affect human health and growth but also impact agricultural production and quality. This shift manifests in increased temperatures, altered precipitation regimes, and a higher frequency of extreme weather events, all of which deeply affect crop phenology, soil moisture, and the intricate balance of agroecosystems. Climate change significantly threatens global rice production, with each degree increase in temperature potentially reducing yields by 3.2% (Zhao *et al.,*2017). Water scarcity may affect 15–20 million hectares of irrigated rice fields by 2025 (Bouman *et al.,*2007), while flooding, especially in rain-fed lowland regions, presents a growing challenge as improved rice cultivars become more sensitive (Dar *et al.,* 2017; Afrin *et al.,* 2018). Moreover, warmer winter temperatures can increase pathogen populations, leading to infections in subsequent crops (Bhadouria *et al.,* 2019; Harvell *et al.,* 2002). Additionally, rising temperatures accelerate insect digestion rates, causing faster crop damage and increased disease spread, contributing to yield loss (Coviella & Trumble, 1999; Gutierrez *et al.,* 2008; Hare, 1992). Changes in precipitation patterns, flash flooding, and severe drought further exacerbate conditions for disease epidemics in both cultivated and wild plants (Jones, 2016).

Introduction to Basmati rice
Rice, *Oryza sativa*, the staple food of nearly one-half of the world's population, contributes over 20% of the total calorie intake of man. But in Asia, where 95% of the world's rice is cultivated and consumed, it contributes 40–80% of the calories of the Asian diet. India, the second-largest rice producer after China, cultivates around 43 million hectares annually (Muthu, 1993).

The word 'Basmati' has been derived from two Sanskrit roots (vas = aroma) and (mati = ingrained). The earliest mention of Basmati has been made in the epic Heer and Ranjha composed by the Punjabi poet Varish Shah in 1766 (Thakral & Ahuja, 1993).

In trade circles, Dehradun Basmati has been famous for generations. The earliest archaeological proof of rice was sourced from excavations at Mohenjodaro and Harappa in Sind and Punjab (now part of Pakistan) together with remains of a cotton culture that dated to the 3rd millennium BC (Oka, 1988). Carbon dating indicates these to be aged more than 8000 years (Sharma & Manda, 1980). Aromatic rice occupies an exceptional rank in Indian culture, not only because of its high quality but because they have been considered auspicious. These highly valued aromatic rice is collectively called "Basmati" and are popular not only throughout Asia but also in Europe and the USA. Lately, the definition of Basmati has been changed to include its other fine-grain qualities.

Characteristics of Basmati rice

Basmati rice is traditionally grown in the Himalayan foothill regions of India and Pakistan and the name is usually associated with this geographical origin (Bligh, 2000). It is generally accepted that good quality Basmati rice is characterized by extra-long superfine slender grains with chalky endosperm and a shape comparable to a Turkish dagger; pleasant and exquisite aroma, sweet taste, dry, fluffy and soft texture when cooked, delicate curvature, low amylose, medium-low gelatinization temperature, 1.5 to 2-fold length-wise elongation with least breadth-wise swelling on cooking and tenderness of cooked rice (Siddiq *et al.*,1997). As a result of all these properties, Basmati rice hails a premium price in the world market. Basmati rice – the scented pearl, is nature's present unique to the Indian subcontinent. The farmer's and miller's concern is to get the high price of produce (both paddy and rice) which is determined by market quality standards comprising of shape, size and colour of rice, percent of milling, hulling and head rice recovery (Ahuja *et al.,*1995).

Climate Change Impact and Social consequences

In the heart of Punjab, farmers have long valued Basmati rice for its fragrant aroma and delicate flavor. However, cultivating this beloved grain faces increasing challenges due to climate change. Basmati rice is vulnerable to pests and diseases like blast and bacterial leaf blight, and the ideal nursery sowing period is the first week of June. Yet, shifting climate patterns complicate this timing. Tall Basmati varieties, which depend on short days for flowering, are particularly impacted by rising temperatures. Cooking quality is influenced by environmental conditions, soil fertility, and management practices, all of which are disrupted as summer temperatures soar past 40 degrees Celsius. Punjab experiences an average of seven heat waves each year, coinciding with the most vulnerable stages of growth. Even a one-degree increase at night can reduce yields by 10%, threatening farmers dependent on stable harvests. Rainfall patterns are also becoming erratic, further complicating rice production.

Yet, amidst these challenges, some silver linings emerge. Rising carbon dioxide levels may enhance plant growth; a doubling of CO_2 could boost harvests by 25%, helping plants thrive with reduced water needs during shortages.

In Jammu's RS Pura region, renowned for premium Basmati, farmers are facing a severe agrarian crisis fueled by climate change and infrastructural neglect. Erratic rainfall and rising temperatures have disrupted traditional growing cycles, leading to declining yields.

Nearly two-thirds of Basmati rice produced in India is exported. The Basmati Rice Market is projected to grow from USD 39.84 million in 2024 to USD 42.75 million in 2025, reaching USD 59.90 million by 2030 (according to a report by ResearchAndMarkets.com), indicating that farmers must enhance production to meet rising demand.

Innovations and Way forward

In response to climate change, farmers and researchers are adopting climate-resilient strategies:

1. Basmati Varieties : New strains are being bred for drought, heat, salinity, and submergence tolerance to adapt to unpredictable weather. Ex: Shaheen basmati, Pusa Basmati 1.

2. Sustainable Practices : Techniques like direct-seeded rice, drip irrigation, and crop diversification aim to conserve water, reduce emissions, and promote soil health.

3. Support Initiatives : Collaborative efforts from government, private exporters, and organizations like the FAO are essential for incentivizing sustainable production and assisting the transition to climate-smart agriculture.

Conclusion

In conclusion, the future of Basmati rice cultivation in India faces significant challenges due to climate change, including rising temperatures, erratic rainfall, and increased pest pressures. Farmers in several regions are already confronting severe agrarian crises, which threaten both their livelihoods and the quality of this cherished grain. However, there is a glimmer of hope with the potential benefits of rising carbon dioxide levels that could enhance plant growth. As the global demand for Basmati rice continues to grow, projected to reach USD 59.90 million by 2030, it is imperative for farmers to adapt their practices and innovate to boost yields and sustainability. Strategic support, investment, and research are crucial to overcoming these hurdles and ensuring the resilience of Basmati rice farming in the face of an uncertain climate future. It's essential to assess the potential impacts of climate change on crop health in a coordinated way.

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Article ID : 05/VIII/46/0825

UNLOCKING THE POTENTIAL OF BABY CORN: A PROFITABLE OPTION FOR FARMERS IN WEST BENGAL

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Abstract

Baby corn (*Zea mays* L.), immature ear of maize, has emerged as a promising high-value crop in India as well as in West Bengal due to its short duration, multiple harvests, and high market demand. The favourable agro-climatic conditions of West Bengal, especially in districts like Hooghly, Nadia, Burdwan, and North 24 Parganas, support year-round cultivation. Farmers are increasingly adopting baby corn due to its profitability, export potential, and suitability for small and marginal landholdings. Its cultivation requires well- drained loamy soils, timely sowing, adequate irrigation, and integrated nutrient and pest management practices. The crop matures within 60-65 days which supports farmers to cultivate multiple crops in a year, thus enhancing cropping intensity and ensuring extra income to the farmers. Government support, training programs, improved seed varieties, and growing demand have further boosted baby corn cultivation. Besides, helping in crop diversification and promotion of dairy industry, baby corn also helps in employment generation and value addition.

Keywords: Baby corn, crop diversification, high value crop, West Bengal

Introduction

Baby corn, the immature ear of *Zea mays* L., is a high-value nutritious vegetable crop harvested 7–10 days after silk emergence, before pollination occurs. At this tender stage, the entire cob is edible which offers a crispy texture, mild flavour, and aesthetic appeal that make it a prized ingredient in a variety of cuisines, especially Indo-Chinese and continental dishes. Its global popularity has surged in recent years India emerging as a prominent producer due to its favourable growing conditions and increasing demand from both domestic consumers and export markets.

Recently, baby corn has been grown in a number of Indian states, including Meghalaya, western Uttar Pradesh, Haryana, Maharashtra, Karnataka, and Andhra Pradesh. In India, West Bengal has shown potential in baby corn cultivation, due to its fertile soils, abundant rainfall, and moderate climate, which are ideal for maize growth. The crop fits well into existing crop rotations and can be cultivated year-round under irrigated conditions, making it an efficient choice for resource-limited farmers. Its short duration nature (60 to 70 days) allows farmers to grow multiple crops annually which increase not only land-use efficiency but also farmer's income. Baby corn can also grow as intercrop for example baby corn + coriander (2:1), baby corn + okra (2:1), baby corn + radish (2:1), baby corn + vegetable cow pea (2:1) etc. which also very beneficial for farmers. Moreover, baby corn is a suitable crop for small and marginal landholders of West Bengal.

Baby corn is a lucrative crop that enables production diversification, value aggregation, and higher revenue. Because of its many uses and high net returns, it has gained popularity among growers in peri-urban areas in recent years. In contrast to other intercropping systems, baby corn as a sole crop produced substantially more corns per hectare, as well as a higher gross return and return per rupee investment.

The crop requires relatively low input costs, and with proper agronomic practices such as timely sowing, adequate irrigation, pest management, and appropriate nutrient application The growing demand from urban markets, food processing industries, hotels, and export agencies further adds to its profitability.

Major Uses of Baby Corn

Baby corn, with its tender texture and mild flavour, has gained immense popularity across culinary, commercial, and agricultural sectors due to its versatility, nutritional value, and market potential.

1. Culinary Uses

In domestic cooking, baby corn is a favourite ingredient in a variety of everyday dishes. It is widely used in stir-fries, especially in Chinese and Thai recipes. Indian households commonly incorporate it into curries and gravies, such as baby corn masala. It also features in popular snacks like baby corn pakora, fritters, and grilled skewers. Its crispness and colour make it a delightful addition to salads, while it is frequently used in soups like hot and sour or sweet corn soup for extra texture. In the restaurant and hotel industry, baby corn holds a significant place in diverse cuisines. It is frequently added to continental dishes like pasta and used as a topping for gourmet pizzas. In Asian cuisine, it finds a place in Thai green curry, noodles, and spring rolls.

2. Processed Products

Baby corn is processed into several value-added forms to extend its shelf life. For example, frozen baby corn, pickles, canned baby corn, dehydrated baby corn etc. are very popular not only in India but all over the world.

3. Fodder and Agricultural Use

After harvesting the cobs, the remaining stalks and husks of baby corn plants serve as excellent green fodder for livestock. The crop residue also has value as organic matter and can be composted and used into the soil as manure to improve soil health and fertility.

4. Export and Trade

Baby corn has strong demand in international markets, particularly in regions like the Middle East, the European Union, and South-East Asia.

5. Nutritional and Health Benefits

There were 23.43 g of total soluble sugars, 1.96 g of reducing sugars, 0.1 g of fat, 1.7 g of protein, 3.6 g of carbohydrates, 1.2 g of dietary fibre, 8.10 g of cellulose, 5.41 g of lignin, 670 µg of βcarotene, 898.62 mg of phosphorus, and 6.25 mg of zinc in 100 grams of baby corn. Iron (2 mg), potassium (483 mg), sodium (158 mg), magnesium (76 mg), calcium (51 mg), and vitamin C (16 mg) are also present in baby corn. Baby corn is gluten-free which makes it suitable for individuals with gluten intolerance or celiac disease.

6. Emerging Uses

Baby corn is also finding new avenues in emerging product segments. Its mild flavour and easy digestibility make it ideal for baby food formulations. The rise of convenience- based cooking has led to the popularity of ready-to-cook kits that include pre-cut, vacuum- sealed baby corn, catering to urban consumers.

Package of Practices for Cultivation

Variety Selection

Using the right variety for cultivation, is important for ensuring a high-yielding baby corn crop. In India, several baby corn hybrids like 'HM4', 'G5414', 'VL Baby Corn 1', and 'PEHM-2' have been found suitable for cultivation. In West Bengal, hybrids like 'Madhuri' and 'Kesari', valued for their adaptability to humid subtropical conditions, uniform cob size, and early silking within 50–60 days.

Land Preparation

Baby corn thrives best in well-drained, fertile loamy soils with a pH range of 5.5 to 7.0, a common soil type in the Gangetic plains of West Bengal. Two to three deep ploughings followed by harrowing is required to achieve a fine tilth. After that 5–10 tons of well- decomposed farmyard manure or vermicompost per hectare can be used. Ridges or raised beds can be formed to manage excess water during the monsoon especially in low-lying areas prone to waterlogging.

Sowing Time

In India, baby corn can be sown during the *kharif* (June–August) and *rabi* (October– December) seasons. For West Bengal, the best planting times are February–March (spring) and October–November (*rabi*), avoiding the peak monsoon period that may hamper germination.

Spacing and Seed Rate

A spacing of 60 cm between rows and 15–20 cm between plants should be given which will accommodate around 60,000 to 80,000 plants/ha. High-quality seed @20–25 kg/ha should be sown at a depth of 3–5 cm. To ensure uniform sowing, a seed drill or dibbling method can be used.

Nutrient Management

Baby corn responds well to balanced fertilization. Nitrogen (N), phosphorus (P_2O_5), and potassium (K_2O) @120, 60 and 40 kg/ha, respectively, should be applied at the time cultivation. Half the nitrogen and the full doses of phosphorus and potassium should be applied at the time of sowing. Top-dressing should be done with the remaining nitrogen about 30 days after sowing to support vegetative growth. To improve soil health and sustainability, farmers can use organic inputs such as neem cake, vermicompost, or biofertilizers like Azotobacter and PSB (Phosphate Solubilizing Bacteria).

Irrigation

Irrigation should be given in the field after sowing to ensure uniform germination. Subsequently, irrigation should be given at every 5–7 days interval depending on soil moisture levels and rainfall. In West Bengal's humid climate, thorough monitoring of field is required for waterlogging, especially in poorly drained soils. Maintaining adequate soil moisture during the silking and cob development stages is critical for cob tenderness and quality.

Weed, Pest, and Disease Management Weed Control

Pre-emergence herbicide such as atrazine at 1 kg/ha may be applied to control early weed. Alternatively, manual weeding at 20 and 40 days after sowing can ensure clean fields, especially where herbicide use is limited.

Pest Control

Common insect pests include stemborers and aphids, particularly under warm and humid conditions. Neem-based biopesticides can be used for eco-friendly control or, where necessary, approved insecticides like carbaryl can be applied.

Disease Management

Fungal diseases such as downy mildew, which thrive in West Bengal's humid climate is a major problem in baby corn cultivation. Ensuring proper field drainage and, if required, application of mancozeb or other recommended fungicides can be done to protect the crop.

Detasseling

Detasseling is the manual removal of tassels (male flowers) from maize plants. It is a crucial practice in baby corn cultivation to enhance cob quality and yield. Unlike grain corn, where detasseling is mainly done for hybrid seed production, in baby corn it serves to prevent pollination, ensuring the cobs remain tender, small, and kernel-free which is ideal for culinary use and export. It is carried out 35–45 days after sowing, just before tassel emergence. Detasseling redirects plant energy towards ear development which results in uniform, high- quality cobs. All plants in a baby corn field must be detasseled. It is performed during cooler parts of the day to minimize stress. Detasseling, when combined with proper nutrition and pest monitoring, can significantly boosts the market value of the crop.

Harvesting

Baby corn should be harvested 7–10 days after silk emergence, when the cobs are still tender and measure about 5–10 cm in length and 1–1.5 cm in diameter. The kernels should be underdeveloped and soft. For best quality and consistent market supply, harvest cobs at every 2–3 days interval, as maturity varies across plants. With proper management, farmers can expect a yield of 1.5 to 2 tonnes/ha of de-husked baby corn. De-husking and cleaning should be done immediately after harvest to retain freshness and visual appeal.

Post-Harvest Handling

Post-harvest operations are crucial for preserving quality and maximizing profits. Sorting and grading should be done to ensure uniformity in size, a critical factor for both fresh market and export. Baby corn should be stored at 0–2°C with 90–95% relative humidity, which helps to maintain freshness up to two weeks.

Conclusion

Baby corn is fast emerging as a profitable niche crop in India. From variety selection and timely sowing to precise detasseling and post-harvest handling, every stage in baby corn cultivation demands careful attention. The crop's short duration, high market demand, suitability for small landholdings, and export potential make it an attractive option for both small and marginal farmers. With regard to urban consumption and international interest, baby corn farming offers a sustainable avenue for income generation, employment, and agricultural diversification. By adopting improved agro-techniques, value-added processing, and efficient marketing strategies, farmers can tap into the full potential of this high-value crop.

Baby corn cob

Dehusked baby corn

ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/47/0825

CHLOROPHYLL *a* ESTIMATION FROM PHYTOPLANKTON: A SPECTROPHOTOMETRIC METHOD

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Introduction

Chlorophyll *a* (chl-a) is a vital photosynthetic pigment in phytoplankton and is widely used as an indicator of algal biomass and primary productivity in aquatic ecosystems. It typically constitutes about 1–2% of the dry weight of phytoplankton.

Table 1: Different types of chlorophyll in plants and their role

Pigment	Found In	Role
Chl-a	All photosynthetic organisms	Primary pigment
Chl-b	Green algae, higher plants	Accessory pigment
Chl-c	Diatoms, brown algae	Accessory pigment
Chl-d	Red algae, cyanobacteria	Low-light adaptation
Chl-f	Some cyanobacteria	Far-red photosynthesis

There are four methods for estimating chlorophyll a in water (Fig. 1).

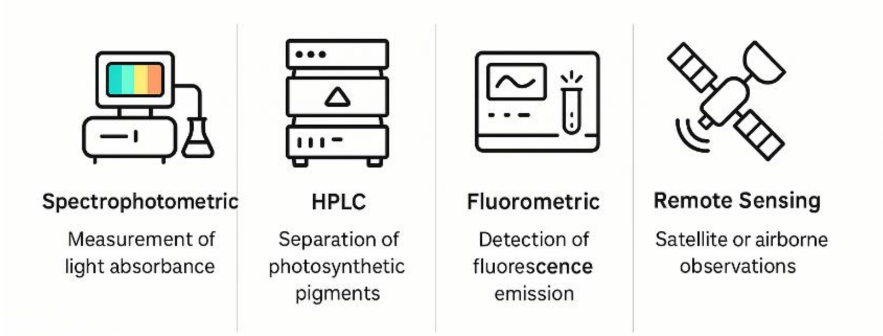

Figure 2: Different methods to estimate chlorophyll a in aquatic systems

Spectrophotometric method for chlorophyll *a* estimation

The spectrophotometric method described by Strickland and Parsons (1972) to estimate chl-a, with careful handling to minimize pigment degradation. Many researchers followed this method in chl-a estimation from phytoplankton as a reliable method (Kumar et al 2015, 2020)

Figure 3: Vacuum pressure filtration unit

Sample Collection and Filtration

- **Sample Volume**: 250 mL of surface water was collected from each site using amber-colored HDPE bottles to prevent light-induced degradation of pigments.
- **Filtration**: Water samples were filtered through 47 mm diameter Whatman GF/C glass fibre filters under low vacuum pressure.

- **Magnesium Carbonate Addition**: During filtration, a few drops of saturated magnesium carbonate ($MgCO_3$) solution were added to the filter paper to prevent acidification and stabilize the chlorophyll pigments.

Figure 4: Glass fibre filtre paper

Extraction Procedure

1. **Grinding**: The filter containing retained material was placed in a clean mortar. About 10–15 mL of 90% acetone was added.
2. **Cell Disruption**: The filter was gently ground with a pestle to rupture phytoplankton cells and release chlorophyll into the solvent.
3. **Transfer and Storage**: The slurry was transferred to a graduated centrifuge tube, capped tightly, and stored at 4°C in the dark for 24 hours for complete pigment extraction.
4. **Centrifugation**: Samples were centrifuged at 2500 rpm for 15 minutes to separate particulates from the chlorophyll-containing supernatant.

Spectrophotometric Measurement

- Absorbance of the clear supernatant was measured using a UV-visible spectrophotometer at:
  - **Before acidification**: 750 nm (W) and 664 nm (X)
  - **After acidification** (after adding 1–2 drops of 1N HCl and waiting for 2–3 minutes): 750 nm (Y) and 665 nm (Z)
- **Purpose of Wavelengths**:
  - **750 nm**: Corrects for turbidity and background noise.
  - **664 nm**: Measures chlorophyll-a.
  - **665 nm after acidification**: Measures pheophytin-a (chlorophyll degradation product).

Calculation of Chl-a Concentration

Corrected absorbance values:

- **664b** = X – W (before acidification)
- **665a** = Z – Y (after acidification)

Formula:

$$\text{Chlorophyll a } (\mu g/L) = \frac{26.7 \text{ x } (664b - 665a) \text{ x V1}}{\text{V2 x L}}$$

Where:

- **26.7** = Absorbance coefficient and conversion factor
- V_1 = Volume of extract (L)
- V_2 = Volume of filtered water sample (m^3)
- **L** = Light path length of cuvette (typically 1 cm)

Data Recording Format

Samples	Absorbance at 750 nm (W)	Absorbance at 664 nm (X)	664b (= W – X)	Absorbance at 750 nm (Y)	Absorbance at 665 nm (Z)	665a (= Y – Z)
	Before acidification			After acidification		

Samples	Absorbance at 750 nm (W)	Absorbance at 664 nm (X)	664b (= W – X)	Absorbance at 750 nm (Y)	Absorbance at 665 nm (Z)	665a (= Y – Z)
Site 1						
Site 2						
Site 3						

Notes on Methodology

- Chlorophyll a exhibits peak absorption at 664 nm in 90% acetone.
- Acidification converts chl-a to pheophytin-a, which alters absorbance and helps correct for degradation.
- Use amber bottles and low light conditions during sampling and extraction to avoid photodegradation.

Preparation of 90% acetone

- Add 100 ml of distilled water to 900 ml of acetone to make one litre 90% acetone solution.

Preparation of Saturated $MgCO_3$ Solution

- Add ~10 g of $MgCO_3$ to 100 mL of distilled water.
- Stir thoroughly and allow the mixture to settle.
- Use only the clear supernatant during filtration.

Preparation of 1% Hydrochloric Acid (HCl) Solution

- 1 mL of concentrated HCl + 99 mL of distilled water to make 100 mL of 1% HCl (typically ~37% w/w, density ~1.19 g/mL) solution.

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ISSN : 2583-0910
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/48/0825

WATERMELON: FRUIT, VEGETABLE, OR BOTH? A BOTANICAL AND CULINARY PERSPECTIVE

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Introduction

Watermelon (*Citrullus lanatus*) stands among the most cherished crops across the globe, especially in tropical and subtropical regions. Known for its sweet, juicy flesh and hydrating properties, watermelon is a staple of summer diets and festivities. While its sugary flavour and refreshing nature point clearly toward a fruit identity, the methods employed in its cultivation often align with that of vegetable crops. This overlap in characteristics across botanical, horticultural, agronomic, and culinary disciplines has led to an intriguing question: Is watermelon a fruit, a vegetable, or does it straddle both categories?

Botanical Classification: Watermelon as a True Fruit

In botanical science, the classification of fruits is based on morphology, specifically the structure and development of reproductive organs in plants. A fruit is defined as the mature ovary of a flowering plant, typically containing seeds and arising from pollinated and fertilized ovules.

Watermelon fits neatly into this definition. It develops from the ovary of the pistillate flower and encapsulates numerous seeds within a soft, edible mesocarp. Botanically, watermelon is categorized as a pepo, a type of fleshy fruit characterized by a thick, hard rind and a succulent interior. This fruit type is commonly associated with members of the Cucurbitaceae family, which includes cucumbers, gourds, squashes, and pumpkins.

Esau (1977) in *Anatomy of Seed Plants* provides a detailed explanation of the fruit formation process that applies to watermelon. The structure is completed with a pericarp that encloses and protects the seeds, affirming its classification as a true botanical fruit. Hence, from a strictly scientific perspective based on developmental anatomy, watermelon is unequivocally a fruit.

Horticultural and Agronomic Perspective: Cultivated Like a Vegetable

While botany offers a rigid definition based on plant structure, horticulture and agronomy rely more on cultural practices and crop management strategies. In these applied sciences, classification often hinges on how a crop is grown, harvested, and utilized in agriculture.

Watermelon is typically direct-seeded in the field and grown as an annual, much like other vegetable crops. It requires similar inputs, including nutrient management, pest control, and irrigation schedules, and is cultivated in the same rotation systems as cucumbers, melons, and squashes. These characteristics align more with standard vegetable production protocols.

Rubatzky and Yamaguchi (2012), in their seminal work *World Vegetables*, classify watermelon within vegetable crops based on its cultural requirements and field practices. Government extension bulletins, production guides, and crop statistics databases in many countries, including India and the United States, also categorize watermelon under the vegetable crop section.

This agronomic treatment affects everything from crop planning to subsidy schemes, breeding programs, and pest surveillance systems. In essence, watermelon is grown like a vegetable but biologically structured like a fruit a contradiction rooted in the diverse approaches of scientific disciplines.

Culinary and Cultural Classification: Watermelon as a Fruit

From a culinary standpoint, classification depends less on plant anatomy and more on flavour profile, texture, and usage in food preparation. In kitchens and dining traditions around the world, watermelon is universally treated as a fruit.

Its naturally sweet taste, high water content, and refreshing flesh make it a popular ingredient in fruit salads, juices, smoothies, desserts, and other cold dishes. Unlike typical vegetables, watermelon is rarely cooked or incorporated into savory main courses, reinforcing its culinary identity as a fruit.

That said, some regional cuisines offer unique uses of watermelon rind. In parts of Asia and the American South, for example, the rind is pickled or stir-fried. While such uses introduce complexity into its classification, they remain niche compared to the dominant sweet usage of the flesh.

Ultimately, in the global culinary lexicon, watermelon occupies the same space as other sweet fruits such as mango, papaya, or pineapple—consumed raw and appreciated for its dessert-like qualities.

Legal and Historical Interpretations: Contextual Classifications

Legal and policy-related contexts have also influenced how produce is classified. A notable example is the U.S. Supreme Court case *Nix v. Hedden* (1893), in which the Court ruled that tomatoes should be taxed as vegetables under tariff laws, despite their botanical classification as fruits. The judgment was based on common culinary use rather than scientific classification.

While no such legal dispute has targeted watermelon specifically, this precedent suggests that classification can be fluid in legal and regulatory settings, influenced more by commerce and public perception than academic consensus.

In some policy documents and trade guidelines, watermelon may be categorized with vegetables for logistical or tariff purposes. This flexible categorization underlines the importance of context what is scientifically accurate may not always align with administrative or economic labelling.

Why the Confusion? Multidisciplinary Lenses on Plant Identity

The ambiguity surrounding watermelon's classification stems from the distinct priorities of various disciplines:

- Botany focuses on internal plant structures and reproductive morphology.
- Horticulture emphasizes field practices, seasonality, and cultivation methods.
- Culinary arts are classified based on taste, texture, and usage in meals.
- Legal frameworks and policy regulations consider trade, tariffs, and cultural perceptions.

Conclusion: Embracing the Dual Identity

Watermelon exemplifies the need to understand classification as a flexible and context-specific concept rather than a rigid label. Botanically, there is no ambiguity—it is a fruit by structure and development. Horticulturally and agronomically, however, watermelon is treated as a vegetable due to its annual growth cycle, field practices, and integration with other vegetable crops.

In culinary terms, its sweet flavour and refreshing characteristics firmly position it as a fruit in popular perception and usage. Meanwhile, policy and legal interpretations may shift classifications based on context, adding another layer of complexity.

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ISSN : 2583-0910
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/49/0825

THE GOLDEN CROP: WHY INDIAN FARMERS ARE TURNING TO OIL PALM CULTIVATION IN KARNATAKA

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Abstract

Oil palm cultivation is emerging as a transformative "golden crop" for Indian farmers, particularly in Karnataka, where rising edible oil demand and strong government policy incentives have driven rapid expansion. This article reviews the trends, economics, and challenges of oil palm in Karnataka, synthesizing data from government and academic sources. While the state currently cultivates only 7,700 hectares-much below its potential-the crop's high yields and steady income prospects have prompted many to switch from traditional crops. Despite advantages like long-term profitability and policy support, challenges such as water intensity, ecological impact, and supply-chain constraints limit adoption. Sustainable management and infrastructure investment are essential to harness oil palm's full potential and achieve greater self-sufficiency in edible oil production.

Keywords: Oil palm, Karnataka, Golden Crop and Edible oil production

Introduction

India is one of the world's largest consumers of edible oils, yet the country heavily depends on imports for fulfillment of its domestic demand. This reliance has economic implications due to fluctuating global prices and foreign exchange outflows. To counter this, Indian policymakers and farmers are increasingly focusing on expanding domestic production of high-yield oilseed crops, with oil palm (*Elaeis guineensis*) emerging as a flagship "golden crop."

Oil palm has been heralded for its high oil yield per hectare-far exceeding traditional oilseed crops like mustard, sunflower, or groundnut. Karnataka, a southern state with suitable agro-climatic conditions and growing farmer interest, stands out in the national dialogue for oil palm expansion. The crop's lucrative returns, government support schemes, and rising demand for edible oils have motivated many farmers to diversify their cultivation patterns toward oil palm (Srilatha, 2015).

This article provides a comprehensive overview of the ongoing transformation towards oil palm cultivation in Karnataka. It explores cultivation trends, governmental policies, economic benefits for farmers, challenges faced in expanding this crop, and the broader implications for the state's agriculture and economy (Manjunatha et. al., 2021).

Materials and Methods

This analysis draws primarily from a variety of official and academic sources:

- Reports and evaluation studies commissioned by the Karnataka Evaluation Authority and Department of Horticulture.
- Statistical data published by the Ministry of Agriculture, National Mission on Edible Oil-Oil Palm (NMEO-OP), and state horticulture departments.
- News articles highlighting farmer experiences and industry-government collaborations.
- Policy documents outlining subsidies, incentives, and regulatory frameworks like the Karnataka Oil Palm (Regulation of Cultivation, Production and Processing) Act, 2013 (Annon. 2013).
- Field-level surveys to assess adoption rates, yields, and economic returns.

These sources collectively provide quantitative data on cultivated area, fresh fruit bunch (FFB) production, yields, subsidy benefits, and profitability. Qualitative insights from farmer case studies and stakeholder interviews round out the methodological approach.

Fig. 1: Oil Palm plant and orchard

Results and Discussion

Cultivation Area and Production Trends in Karnataka

Oil palm cultivation in Karnataka began in the early 1990s and has since experienced fluctuating growth. The current area under oil palm cultivation (2024) is approximately 7,700 hectares, generating about 13,000 tonnes of Fresh Fruit Bunches (FFBs) with an average yield of 1.69 tonnes per hectare. This shows significant improvement from historical yields of 1.20 tonnes per hectare on around 5,000 hectares (Annon. 2024a).

However, these figures represent just a fraction of Karnataka's estimated potential oil palm cultivation area of 250,000 hectares. The developed area, where best practices are implemented and irrigation is adequate, reports yields as high as 2.81 tonnes per hectare. Yet, about two-thirds of the developed area has been converted back to other crops due to challenges faced by farmers, highlighting the current constraints on widespread adoption.

Table 1: Area, production and productivity of oil palm

State Category	Area Under Cultivation (ha)	Production of FFBs (tons)	Yield per Hectare (tons/ha)
Current Karnataka (2024)	7,700	13,000	1.69
Historical Karnataka	5,000	6,000	1.20
Potential Karnataka	250,000	—	—
Developed Area Karnataka	35,000	10,114	2.81

Source: Karnataka renews thrust on oil palm

Government Policies and Incentives
Government commitment underpins Karnataka's growing role in oil palm cultivation. The National Mission on Edible Oil-Oil Palm (NMEO-OP), launched in 2021, aims to triple oil palm cultivation area in India to one million hectares by 2025-26 and drive crude palm oil production to over 1.12 million tonnes. Karnataka is a key beneficiary of this scheme.

Key policy supports include:

- Financial subsidies covering up to 85 per cent of planting material costs and 50 per cent of other inputs such as drip irrigation and fertilizers.
- Specific state subsidies that provide up to ₹15,500 per farmer over four years and assistance up to ₹45,000 for borewell drilling and implements.
- A regulatory framework through the Karnataka Oil Palm Act (2013) that organizes cultivation coordination between growers and processors, ensuring quality and timely procurement of FFBs.
- Minimum price fixation committees to guarantee fair pricing for farmers, avoiding price exploitation.
- Institutional support through public-private partnerships, such as the recent MoU between Karnataka's Horticulture Department and 3F Oil Palm, aiming to provide farmers with advanced technologies and sustainable cultivation practices (Annon. 2024b).

These policy measures have successfully boosted farmer confidence and investment in oil palm, despite the crop's long gestation period.

Economic Benefits for Farmers
The primary driver for the shift toward oil palm cultivation is its economic advantage

- **High Oil Yield:** Oil palm produces 10 to 46 times more oil per hectare compared to traditional oilseed crops like mustard or sunflower, making it exceptionally productive.
- **Revenue Potential:** Once mature (4-5 years post-planting), oil palms provide regular monthly yields for about 20-25 years. Farmers can earn between ₹90,000 to ₹1,00,000 per acre annually from FFB production under optimal conditions.
- **Steady Income Stream:** Unlike seasonal crops with one or two harvesting cycles, oil palm provides year-round income, stabilizing farmer cash flow.
- **Long-Term Returns:** Over its nearly 30-year productive lifespan, a single hectare of oil palm can yield returns exceeding ₹15 lakh, depending on yield and market price conditions.

Farmers in Dakshina Kannada district, for example, have reported earnings of up to ₹21,300 per tonne of palm fruit, with increasing demand pushing prices higher over recent years. This financial viability makes oil palm an attractive alternative, especially in regions facing issues with traditional crops affected by diseases or environmental stresses.

Challenges and Environmental Concerns
Despite its promises, oil palm cultivation confronts several ecological, agronomic, and socio-economic challenges that hinder its expansion in Karnataka and India at large:

- **Water Intensive Crop:** Oil palms require substantial water, approximately 250-300 liters per plant daily, making irrigation critical. Regions with erratic monsoons or inadequate water infrastructure pose high risks for cultivation.

- **Soil Health:** Large quantities of chemical fertilizers and pesticides are often needed, potentially degrading soil fertility over time.
- **Long Gestation Period:** The crop takes 4-5 years to mature and produce fruit, requiring farmers to sustain costs without immediate returns, which can be discouraging for smallholders.
- **Logistical Constraints:** FFBs must be processed within 24-48 hours of harvest to maintain oil quality. Lack of proximate processing mills and poor rural transport infrastructure complicate timely processing and reduce profitability.
- **Social Impacts:** The long-term land commitment locks land resources for decades, possibly limiting farmers' cropping choices and altering land tenure patterns. There are concerns about community land being captured by large landholders due to this lock-in.
- **Biodiversity Loss:** Monoculture oil palm plantations reduce local biodiversity and can disrupt ecosystems. This has been seen notably in the northeast Indian states but is a relevant caution for Karnataka as well.

Overall, sustainable water management, soil conservation initiatives, and strengthening of supply chain infrastructure are critical to overcoming these hurdles.

Case Studies and Farmer Experiences

Farmers transitioning from traditional crops such as arecanut and paddy to oil palm have experienced mixed outcomes:

- In Dakshina Kannada district, farmers encouraged by the horticulture department's support have seen improved income stability and crop diversification benefits. The shift was also motivated by arecanut's susceptibility to yellow leaf disease (Annon. 2022b).
- The partnership between Karnataka's Horticulture Department and private firms like 3F Oil Palm brings advanced agri-technologies, training programs, and community empowerment, fostering sustainable cultivation.
- However, evaluation studies by the Karnataka Evaluation Authority indicate that returns may be overestimated for small and marginal farmers, and some farmers have reverted to other crops due to inconsistent price realization and water shortages.

The lessons suggest that oil palm cultivation suits better those with access to larger landholdings, assured irrigation, and reliable market linkages.

Conclusion

Oil palm cultivation in Karnataka holds significant promise as a transformative crop contributing to India's edible oil self-sufficiency ambitions while potentially enhancing farmer livelihoods. The crop's high productivity, continuous income generation, and supportive government policies make it an attractive alternative to traditional crops.

However, realizing this potential fully demands addressing substantial challenges—water management, soil health, infrastructure deficits, processing capacity, and social equity. Strategic investments in irrigation, mill facilities, and supply chain efficiencies, alongside environmentally sustainable practices, will be crucial. Karnataka's experience highlights the balance needed between rapid expansion and sustainable, inclusive growth in oil palm. With continued policy support and innovative farmer engagement, oil palm can indeed become the "golden crop" driving the state's agricultural and economic resurgence.

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ISSN : 2583-0910
Agri-India TODAY
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Peer reviewed
monthly newsletter

Article ID : 05/VIII/50/0825

BREEDING WITHOUT SEEDS: INNOVATIONS IN CLONAL CROP IMPROVEMENT

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Abstract

Clonal crop breeding plays a crucial role in improving vegetatively propagated crops such as potato, cassava, and banana. These crops require specialized breeding strategies due to their high heterozygosity and reliance on vegetative propagation. This article highlights the key approaches including crossbreeding using selected protocols, analytical breeding via ploidy manipulation, and the use of somaclonal variation from tissue culture. Evolutionary breeding is also discussed, with a focus on broadening the genetic base in crops like triploid bananas and plantains using diploid crosses. The potential of synthetic populations through Polycrossing methods further complements genetic enhancement. By integrating traditional methods with modern innovations and molecular tools, these strategies ensure the development of high-performing, stress-tolerant clonal varieties. The integration of genetic diversity from wild species offers immense promise for sustainable crop improvement and long-term food security in the face of environmental and biotic stresses

Keywords: Clonal Propagation, Analytical Breeding, Ploidy Manipulation and Synthetic Population

Introduction to Clonal Propagation

Clones are reproductive organs that result from asexual (or vegetative) reproduction. The main vegetatively propagated food crops are potatoes, cassava, sweet potatoes, yams, plantains crops, sugar cane and fruit trees. Other crops with asexual reproduction include some ornamentals, grasses, and forage crops. The most common planting materials include tubers (e.g., potatoes and yams), vines (sweet potatoes), stem cuttings (cassava), and suckers (plantains and bananas). In the case of vegetatively propagated crops, the common origin of the planting materials is crucial for uniform experiments. Plantlets obtained from tissue culture are also promising planting materials for achieving dispersal uniformity in some of these food plants.

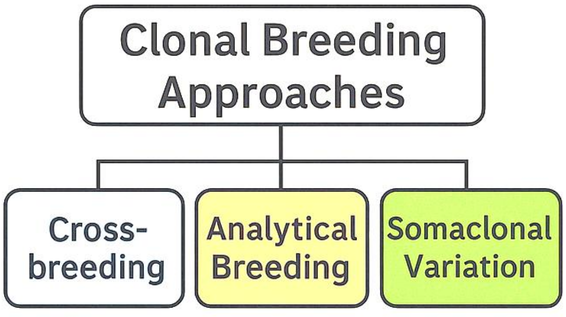

Figure 1. Clonal Breeding Approaches

Crossbreeding in Clonal Crops

Crossing methods for vegetatively propagated crops rely on sexual hybridization, i.e. seeds are needed to produce new genotypes after crossing selected parents. Therefore, special protocols are used to maximize flowering in some vegetatively propagated crops. Time (i.e. photoperiod) and light intensity are among the most important factors affecting the flowering of these plants.

The main goal of breeding clones will be to obtain genotypes that are phenotypically uniform (homogeneous) but often highly heterozygous, particularly when non-additive gene action controls the commercial trait(s) of interest. Non-additive gene action can arise from intra- or interallelic (epistasis) interactions.

The conventional plan for breeding clones consists of: 1) selecting appropriate parents for crossbreeding schemes; 2) early or late selection in clonal generations, determined by the heritability of the target trait(s); and 3) appropriate environmental sampling (i.e. number of sites and years) for testing advanced breeding materials leading to cultivar development.

Analytical Breeding and Ploidy Manipulation

Genetic manipulations of complete sets of chromosomes are called ploidy manipulations: increasing and decreasing the number of chromosomes of a species within a polyploid series. The major vegetatively propagated food crops (potatoes, sweet potatoes, yams, plantains, and some fruit trees) have well-endowed genetic resources from their wild species, which often exhibit lower ploidy. Chromosome sets are manipulated with haploids, 2n gametes and through interspecific interploidy crosses.

Analytical breeding schemes rely primarily on ploidy manipulations to capture exotic (wild or unadopted) germplasm diversity, and use 2n gametes to represent this genetic diversity through unilateral (USP; n2n or 2nn) or bilateral (BSP; 2n2n) incorporate polyploidization. Haploids are reproductive organs with the gametophytic chromosome number (n) and 2n gametes possess the Sporophytic chromosome number of the parental source.

The most interesting examples of analytical breeding are vegetatively propagated species such as potatoes, yams and cassava among roots and tubers, and plantains/bananas among fruit crops. This breeding approach seems promising in sugar cane, blackberry, blueberry, strawberry and other fruit crops. The potato can be viewed as a model plant either for breeding clones by conventional methods or for broadening the genetic base of plant production, particularly through analytical breeding.

In potato ploidy manipulations, chromosome sets are easily managed using wild types, maternal haploids obtained by parthenogenesis, 2n gametes derived from meiotic mutants, and endosperm balance number (EBN). This endosperm dosing system, common to other angiosperm genera, requires a 2:1 ratio of maternal to paternal contributions to achieve normal seed development after hybridization. The wild species (mostly diploids) bring new genetic variations into the breeding pool, while haploids capture this genetic diversity by crossing them with diploid wild species.

The resulting hybrids of haploid species producing 2n gametes and the EBN are the means of broadening the genetic base of the cultivated potato by USP or BSP, which recent analysis using genetic markers has confirmed. In addition, such an analysis suggests that the need for broadening the genetic base in potatoes may be met by specific chromosomes or regions within chromosomes.

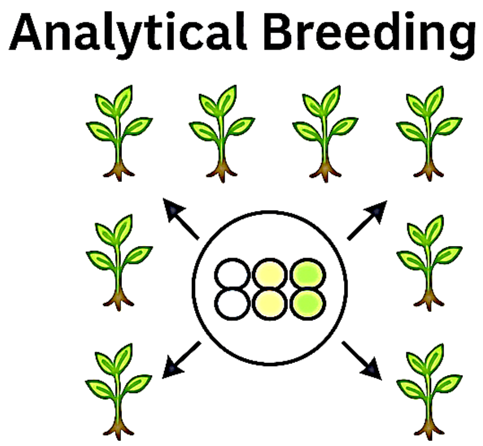

Figure 2. Analytical Breeding in Clonal Crops

Evolutionary Breeding Approaches

Genetic bottlenecks could arise during the evolution of vegetatively propagated crops as breeders of these crops (early farmers but now mostly trained professionals) select some mutants with the desired trait that could replace old cultivars in a large area. Triploid plantains provide an interesting example where most of the variation observed in approximately 120 cultivars (or landraces) known worldwide is due to mutations occurring over the history of the cultivation of this crop and the selection of a few strains by the farmers have accumulated.

In this triploid culture, gene flow was prevented by the pollen due to the low male fertility of the culture. Diploid banana species and plantains that produce 2n eggs have been the tools to broaden the genetic base in this important tropical starch crop.

Tetraploid hybrids can be obtained by hybridizing plantain eggs with n pollen from diploid accessions. Diploids derived from plantains also result from such crossings. In plantains, heterozygous triploid clones (which have long been selected by farmers) are the sources of allelic diversity. These alleles are delivered to the tetraploid hybrids by 2n eggs and are further broadened by the alleles provided by the diploid bananas.

Advanced ploidy manipulations can result in secondary triploids resulting from crosses between selected elite tetraploid and diploid strains, both producing n gametes. Triploid Musa hybrids can also occur as a result of USP among selected diploid stocks, as one of the parents produces 2n gametes. Such plantain breeding methods should be considered as part of an evolutionary improvement approach, as conventional breeding is improved by innovative, knowledge-based methods, as described above, for introducing additional genetic variations. Genetic markers can aid in the process of recurrent selection in plantain germplasm, and the combination of ability tests will aid in the selection of elite parents at any ploidy level.

Somaclonal Variation in Tissue Culture

Irrespective of the advantages of tissue culture for vegetatively propagated crops, Somaclonal variation may affect the true-to-type during micropropagation. Somaclonal variation refers to genetic variation arising from tissue culture regeneration among plants from the same original genotype.

Thorough plant breeders minimize Somaclonal variation by: 1) selecting deliberately stable sources of materials for primary explants; 2) limited subculturing and multiplication (less cycles, short time for subculturing, and a few hundred plants per primary explant); and 3) nursery screening to detect and rogue off-types. Somaclonal variation may provide a potential source for genetic improvement of some vegetatively propagated crops. However, in most crops, the range of Somoclonal variants recovered through shoot-tip culture seems to be narrow, mimics naturally occurring variation, or produces defective genotypes.

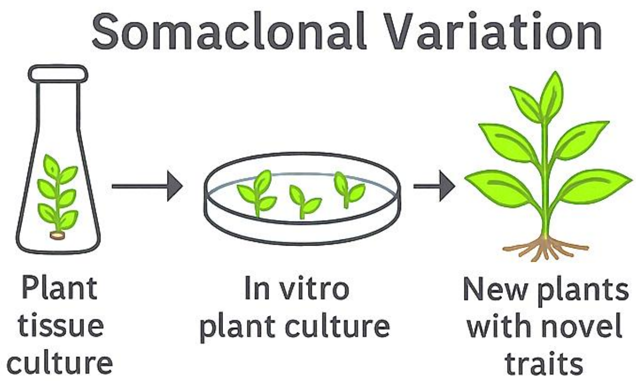

Figure 3. Somaclonal Variation through In Vitro Plant Culture

Synthetic Populations

Hybrid clones can result from artificial hand pollination or from polycrosses between parents selected for their specific ability to combine. Polycrossing refers to a pollination system based on natural random mating between selected genotypes bred together in isolated plots. The seeds from the multiple hybrid mixes can also be considered synthetic strains as they come from selected genotypes that mix well with each other.

A recent report on potatoes suggests that it will be possible to achieve the same or better performance with a minimal number of parents in the synthetic starting population and by allowing them to freely pollinate in an isolated plot. Hybrid seeds from polycrosses are obtained from isolated plots to avoid contamination with pollen from other unselected clones.

Synthetic populations derived from these polycrosses are tested elsewhere to identify promising progeny for selection and variety development. Local selections follow a dynamic conservation approach to genetic resources as target farmers conserve distinct, locally adapted and enhanced genotypes across sites.

Ploidy manipulations coupled with this breeding approach broaden the genetic base of vegetatively propagated crops, thereby improving crop adaptation and maintaining genetic gain in respective breeding pools. As previously mentioned, early locally adapted germplasm with improved adaptation to stress-prone environments or resistance to pests and diseases will enable the sustainable and environmentally friendly production of vegetatively propagated crops, often affected by many biotic or abiotic stresses.

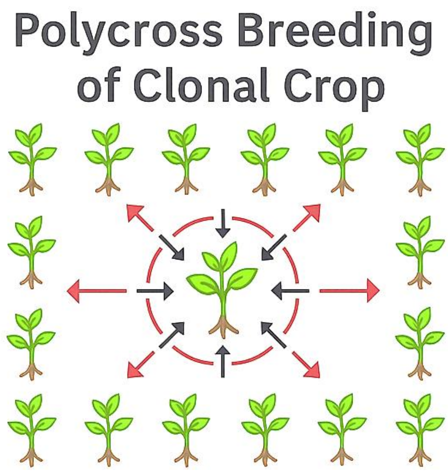

Figure 4. Polycross Breeding Scheme in Clonal Crops

Conclusion and Future Prospects

The genetic improvement of clonally propagated crops remains a complex but rewarding endeavour, especially in the context of rising climate and food security challenges. Crossbreeding methods, when complemented by ploidy manipulation strategies such as the use of 2n gametes and haploids, have proven effective in harnessing diversity from wild germplasm. The integration of somaclonal variation, although needing careful control, offers novel allelic combinations for improvement. Evolutionary breeding in crops like plantain has already expanded the genetic base of cultivated varieties, while synthetic populations provide a robust path for recurrent selection. Future research should prioritize genome editing, high-throughput phenotyping, and marker-assisted selection to fast-track elite clonal cultivar development. Enhanced molecular characterization of ploidy levels and somaclonal variants will enable more precise breeding interventions. Overall, a multidisciplinary approach combining traditional breeding with molecular genetics and biotechnology is essential for the continued improvement of clonally propagated crops under diverse environmental conditions.

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