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ARTICLE ID: 01

Approach Saddle Grafting: A Nextgen Propagation Technique for Fruit Crops

Abstract

The term "saddle graft" combines the words "saddle," a term referring to a structure resembling a seat typically used on a horse, and "graft," which comes from the Late Latin word "graftare," meaning to insert a shoot. In this method 4-6 month old rootstock (5-10 mm) and scion shoot age 3-5 month required for this grafting technique except sapota. For Sapota, age of khirni rootstock required 12-15 month but age of scion must be required 5-6 month old. The size of polybag 4x6 to 6x8 inch which is used for rootstock. In this method more than 50 to 150 grafts prepared from single plant based on their age and shoots with very high grafting success (>80-90%).

Key words: Rootstock, Scion, Saddle graft, Age, Success.

Introduction:

Mostly, fruit plants propagated by variety of grafting techniques across different regions, including veneer grafting, epicotyl grafting, softwood grafting, inarching and cleft grafting, each showing varying degrees of success depending on local conditions. Earlier this term "saddle grafting" originated in the late 1700s, with the earliest noun use in the writing by J. N. Morse in 1792, according to the Oxford English Dictionary. Saddle grafting is the joining a scion onto a rootstock with a particular shape of cut called a saddle. Saddle grafts can be done as bench grafting. The term "saddle graft" combines the words "saddle," a term referring to a structure resembling a seat typically used on a horse, and "graft," which comes from the Late Latin word "graftare," meaning to insert a shoot. The saddle shape made during the grafting process likely inspired the term, as the scion "sits" over the rootstock.

Invention for refining Saddle to Approach Grafting

New grafting technique developed by scientists of Fruit Research Station, Gandevi and Regional Horticultural Research Station, Navsari Agricultural University, Navsari research for propagation of this technique from year 2021 to 2025. In this context, The both side cut on the top of rootstock in inverted 'V' shape which is inserted in scion branch of the mother plant which have same size deep cut, after that injecting of rootstock into scion and grafted part will be tied with polythene strip than whole graft tied with plastic thread on pole for reduce the load on mother plant *i.e.* approach grafting method. That's why given the name to this technique is **Approach Saddle Grafting**.

The graft will detach 3 month later from the mother plant. this method applied on mother plant of different fruit crops *viz*, Mango, Sapota, Guava, Custard apple, Jackfruit *etc*. and got very high grafting success (>80-90%). In this method of grafting age of scion and rootstock vary with th but age of scion must be required 5-6 month old. The size of polybag 4x6 to 6x8 inch which is used for rootstock. In this method more than 50 to 150 grafts prepared from single plant based on their age and shoots.

Importance of Approach Saddle grafting

This method of grafting with flexibility in timing, it can be performed almost year round, offering greater convenience and scheduling according to nurserymen. This adaptability, combined with its efficiency, makes it a valuable technique for large-scale propagation. In saddle grafting, the success rate is influenced by several critical factors, foremost among them being the age of both the scion and the rootstock. Saddle grafting ensures excellent cambial contact, resulting in a strong and stable graft union. The rootstock used in saddle grafting is typically 3 to 6 months old, making it more economical and easier to handle than the younger, more delicate rootstocks used in epicotyl grafting. It is also less mature than the rootstocks required for approach grafting.

Importance of Scion in Approach Saddle Grafting

Scion age plays a vital role in graft success as it directly affects callus formation, vascular differentiation and compatibility with the rootstock. Younger scions typically exhibit higher metabolic activity, which promotes faster healing and stronger graft union development. In contrast, older scions may have diminished regenerative capacity, resulting in lower graft success rate.

Importance of Rootstock in Approach Saddle

fruit crops. However, in most of fruit crops very tender 4-6 month old rootstock (5-10 mm) and scion shoot age 3-5 month required for this grafting technique except sapota. For Sapota, age of khirni rootstock required 12-15 mon

Grafting

The rootstock serves as the foundational support for the grafted plant, responsible for water and nutrient absorption, disease resistance and contributing to overall tree vigour. The age of the rootstock significantly affects graft success by determining the availability of essential carbohydrates, auxins and other growth regulators that facilitate callus proliferation and graft healing. While younger rootstocks generally display greater physiological activity, accelerating callus development, excessively young rootstocks may lack adequate lignification and structural strength, making them susceptible to environmental stresses. Conversely, older rootstocks possess more developed vascular systems but may show reduced growth vigour, potentially slowing graft union formation.

Advantage of Approach Saddle Grafting

1. Round the year grafting is possible
2. 2-3 times grafting on the same mother plant in a year
3. Rootstock in younger age for grafting.
4. Rootstock and scion in fast growing age.
5. Strong and quick union.
6. High success rate.
7. Graft having 2-4 feet height with 2-3 branches.
8. Reduce the cost of graft

Limitations

1. Required technical skilled person
2. Required structure for support for gain weight of grafts

Method of Approach Saddle Grafting:

A saddle graft is a plant propagation technique where the base of a scion shoot on mother plant is shaped into a deep cleft or V-shape, and the top of the rootstock (the host plant) is prepared to have a matching wedge-shaped notch, allowing them to fit together "saddle-wise" like a saddle on a horse. The primary goal of this method to ensure the cambium layers of both the scion and rootstock are in close contact to facilitate successful union and growth of the new plant. The procedure of Approach Saddle Grafting as below:

Procedure for Approach Saddle Grafting

- **Preparing the Stock**: The Rootstock cut transversely at 10-15 cm above the ground level and then two upward cuts are made on either side by the grafting knife. The resulting cut should resemble an inverted 'V' shape with the surface of the cuts ranging from 3-5 cm long
- **Preparing the Scion.** The knife should penetrate more deeply into the wood as the cuts are lengthened. Now reverse the technique to prepare the base of the shoot on the mother plant. Insertion of 3-5 cm deep cut (^ -saddle) by the sharp knife on the scion shoot of the mother plant.
- **Inserting the Scion**: Place the rootstock in the saddle (^) notched scion shoot on the mother plant. Grafted part tied and cut surfaces are sealed by polythene until the graft-union is formed. Care should be taken to avoid gap between the joints. These cuts on the rootstock and scion must be the same length and have the same slope so that a maximum amount of cambial tissue will make contact when the two halves are joined.
- **Securing the Graft**: For overcome the load on mother plant, graft with bag (Scion Shoot and Rootstock plant) should be tied on pole with plastic thread.
- **Detachment:** However, the graft should be detached from mother plants after 3 month.
- **Table: 1. Important items required for Approach Saddle Grafting**

S. No.	Particulars
1.	Secateur
2.	Grafting knife
3.	Small Sickle
4.	Polythene strip
5.	Bamboo
6.	Broad Plastic thread
7.	Skilled person for grafting

Table: 2. Age of rootstock and Scion with success of Approach Saddle Grafting in different fruit crops

S. No.	Name of crop	Age of rootstock	Age of scion	Success of Grafting (%)	Duration (Days)
1.	**Mango**	4-6 month	4 month	85.00	85-90 days
2.	**Custard apple**	4-8 month	4 month	85.50	75-80 days
3.	**Guava**	5-6 month	4-5 month	88.50	75-80 days
4.	**Jackfruit**	5-6 month	5 month	80.20	85-90 days
5.	**Sapota**	10-15 month	5 month	90.00	80-90 days

<u>STAGE WISE PHOTOGRAPHS OF APPROACH SADDLE GRAFTING METHOD IN DIFFERENT FRUIT CROPS</u>

		
Rootstock of mango for Approach Saddle grafting	**Insertion of cut into Scion branch inverted "V" (^) shape**	**Sharp upward cut on Root-stock in inverted "V" (^) shape**
		
Approach Saddle Graft of mango	**Approach Saddle Grafting on mother plant with structure**	**Successful Approach Saddle grafting of mango @ 6 month age of rootstock**
		
Rootstock of Khirni	**Approach Saddle graft on mother plant with structure**	**Successful Approach Saddle graft of sapota**

		
Rootstock of Guava	**Insert the rootstock in scion branch of mother plant**	**Approach Saddle graft of Guava on mother plant**
		
Rootstock of Custard Apple	**Preparation of rootstock with upward inverted ‘V’ shape cut**	**Insertion of cut in scion branch of mother plant**
		
Insert the rootstock into the scion branch	**Structure for Approach Saddle grafting Custard Apple**	**Preparation of Approach Saddle grafting**

Approach Saddle grafting in Jackfruit

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ARTICLE ID: 02

From Sacred Offerings to Sustainable Innovation: Upcycling Floral Waste into Bioplastics and Natural Dyes

The hidden cost of beauty:

India's vibrant culture is steeped in floral traditions. From temple rituals to weddings, flowers symbolize purity, devotion and celebration. But once the ceremonies end, these blooms—often soaked in synthetic colors and pesticides—are discarded in rivers, landfills or streets. This leads to:

- Water pollution from chemical leaching
- Methane emissions from decomposition
- Waste management challenges in urban areas

With over 800 million tons of floral waste generated annually in India alone, the environmental toll is staggering. Yet, this waste holds untapped potential.

The Science of Petal Power

Flowers contain natural pigments like:

- Anthocyanins (reds, purples)
- Carotenoids (yellows, oranges)
- Flavonoids (varied hues)

These compounds are biodegradable, non-toxic and ideal for dyeing textiles, paper and even cosmetics. Extraction methods include:

- Aqueous soaking (water-based)
- Ethanol or methanol extraction
- Steam distillation for essential oils

Researchers in Kerala successfully extracted dyes from *Rosa chinensis* and *Caesalpinia pulcherrima*, achieving vibrant shades on cotton and silk with excellent wash and rub fastness.

Temple Waste as a Resource:
Temples are epicenters of floral waste. Initiatives like HelpUsGreen in Uttar Pradesh collect discarded flowers daily and transform them into:

- Incense sticks
- Compost
- Natural dyes
- Biodegradable packaging

This model empowers rural women, reduces pollution, and creates a circular economy. In Delhi, researchers used marigold and rose petals for eco-printing on cotton fabrics, achieving sustainable fashion outcomes.

Bioplastics—A Blooming Alternative:
Bioplastics are made by combining flower biomass with starches or cellulose. Benefits include:

- Biodegradability: Decomposes in weeks
- Non-toxicity: Safe for food packaging
- Versatility: Can be molded into bags, wrappers, containers

Startups are experimenting with blends of floral waste and agricultural residues to improve strength and flexibility. Imagine receiving a bouquet wrapped in a biodegradable film made from yesterday's temple offerings—pure poetic sustainability.

Natural Dyes in Fashion and Textiles
Synthetic dyes dominate the textile industry but pose health and environmental risks. Natural dyes from floral waste offer:

- Eco-friendliness
- Soft, lustrous colors
- Preservation of cultural heritage

A study by CSIR-NBRI in Lucknow used marigold waste to dye silk fabrics without chemical solvents, achieving vibrant coloration and high fastness ratings. This innovation aligns with green chemistry principles and sustainable fashion goals.

Cultural and Economic Impact
Upcycling floral waste isn't just ecological—it's cultural and economic:

- Preserves traditional dyeing techniques
- Creates jobs in rural and urban areas
- Supports artisans and small businesses
- Promotes eco-tourism and sustainable branding

By turning waste into value, communities reclaim ownership of their environment and heritage.

Challenges and Limitations
Despite its promise, floral waste upcycling faces hurdles:

- Logistics: Coordinating collection from multiple sites
- Preservation: Flowers degrade quickly
- Standardization: Color consistency can vary
- Awareness: Limited public knowledge of benefits

Solutions include mobile collection units, cold storage, and public-private partnerships to scale operations.

Policy and Institutional Support
Government and academic institutions are beginning to recognize the value of floral waste:

- Startup India supports eco-entrepreneurs
- CSIR labs conduct dye extraction research
- Municipal bodies collaborate on waste segregation

Incentives for composting, dye production, and bioplastic innovation can accelerate adoption and commercialization.

The Global Perspective

India isn't alone. Countries like:

- Thailand: Use lotus waste for paper and dyes
- Japan: Upcycle cherry blossom waste into cosmetics
- Netherlands: Convert tulip waste into biofuel

India's rich floral culture gives it a unique edge in leading this global movement. Exporting eco-dyes and bioplastics could open new markets and elevate India's green tech reputation.

A Petal-Powered Future

Floral waste upcycling is more than a trend—it's a philosophy. It honors the sacredness of flowers by giving them a second life, one that nurtures the planet instead of polluting it.

As consumers, we can support this movement by:

- Choosing products made with natural dyes
- Supporting eco-conscious brands
- Advocating for sustainable temple practices

In the end, every petal has a purpose. And with innovation, tradition and care, even the most delicate bloom can become a powerful agent of change.

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ARTICLE ID: 03

Farmer ID: A Boon for Farmers in Uttar Pradesh

Abstract

Agriculture is the backbone of Uttar Pradesh's economy, providing livelihood to over half of its population. Despite this, farmers often face barriers in accessing subsidies, credit facilities, and welfare schemes due to lack of proper identification and transparent systems. To overcome these challenges, the Uttar Pradesh government has introduced the Farmer ID (Kisan ID) initiative, designed to create a centralized digital identity for farmers. This article explores the significance of Farmer ID, its benefits, challenges in implementation, and its role in transforming agriculture in Uttar Pradesh. It argues that Farmer ID is not merely an identification system but a tool for empowerment, transparency, and sustainable growth in the state's agricultural sector.

Introduction

Agriculture in Uttar Pradesh is not just an occupation; it is a way of life. With fertile plains, diverse cropping patterns, and a rich agrarian heritage, the state contributes significantly to India's food grain production. However, for decades, farmers have faced systemic challenges such as delayed subsidies, limited access to credit, and exclusion from government schemes due to lack of verified records.

To address these issues, the Uttar Pradesh government launched the Farmer ID system. This initiative aims to assign a unique identification number to every registered farmer, thereby building a comprehensive database to streamline benefits and ensure inclusivity. Much like Aadhaar transformed social welfare delivery, Farmer ID promises to bring a new era of transparency and efficiency to the agricultural sector.

What is Farmer ID ?

Farmer ID, also known as Kisan ID, is a unique digital identification number provided to farmers after registration. It acts as an official recognition of the individual as a farmer in the state database. This ID links the farmer to multiple government schemes, agricultural loans, crop insurance, and market access platforms.

The objective is two fold:

1. Identification – creating a verified record of genuine farmers.
2. Integration – linking all major agricultural schemes and services to a single digital identity.

Thus, Farmer ID becomes a gateway to empowerment for the farming community.

Importance of Farmer ID in Uttar Pradesh

The introduction of Farmer ID is significant for a state like Uttar Pradesh, where agriculture sustains millions of families. Its importance can be highlighted in the following ways:

- Direct Benefit Transfer (DBT): Ensures subsidies on seeds, fertilizers, and machinery
- directly reach the farmer's bank account without middlemen.
- Financial Inclusion: By linking with the Kisan Credit Card (KCC), farmers can avail low - interest loans with reduced paperwork.
- Insurance Security: Registration under Farmer ID simplifies enrollment in schemes like Pradhan Mantri Fasal Bima Yojana, safeguarding farmers from crop losses due to natural disasters.
- Data-driven Policies: A centralized farmer database helps the government analyze crop trends, soil health, and region-specific challenges to design more effective policies.
- Fair Market Access: Integration with e-mandi platforms ensures farmers can sell their produce at competitive prices without exploitation.

Farmer ID and Digital Empowerment

One of the most powerful aspects of Farmer ID is its alignment with the government's vision of Digital India. By digitizing agricultural records, Farmer ID:

- Simplifies access to subsidies and schemes.
- Provides real-time updates to farmers through SMS or mobile apps. Enhances transparency in distribution of resources.
- Connects farmers to online training, weather alerts, and market rates.
- This digital empowerment reduces dependency on intermediaries and increases farmers'
- bargaining power.

Challenges in Implementation

Despite its potential, the rollout of Farmer ID faces some practical hurdles:

- Awareness Gap: Many farmers, especially smallholders, are unaware of the registration process.
- Technical Barriers: Limited internet connectivity and low digital literacy in rural areas hinder widespread adoption.
- Data Accuracy: Maintaining an error-free database of millions of farmers is a continuous challenge, with risks of duplication or incorrect details
- Inclusion of Tenant Farmers: Sharecroppers and tenant farmers often lack land ownership documents, making registration difficult.
- If left unaddressed, these challenges may reduce the effectiveness of the initiative.

Case Studies and Early Impact

- Although still in its expanding stage, the Farmer ID initiative has shown promising results:
- Timely Subsidies: Farmers who registered early reported faster access to fertilizer and seed subsidies.
- Improved Credit Flow: Banks have begun

recognizing Farmer ID as a credible verification tool for sanctioning agricultural loans.

- Insurance Claims: Linking crop insurance with Farmer ID has simplified claim settlements for farmers affected by floods and droughts.
- These early outcomes reflect the transformational potential of the initiative.

The Road Ahead

For Farmer ID to truly achieve its objectives, the following steps are essential:

- Awareness Campaigns: Village-level meetings, panchayat announcements, and radio programs should educate farmers about the benefits of Farmer ID.
- On-Ground Support Centers: Local kiosks and cooperative societies must assist farmers in registration and troubleshooting.
- Inclusion Policies: Special provisions should be made for tenant farmers, women farmers, and landless laborers to ensure equitable access.
- Integration with All Schemes: Farmer ID should serve as a single window system for every agricultural service, from crop advisory to export assistance.
- Continuous Updating: Regular data verification and updating should be prioritized to maintain accuracy.
- By implementing these measures, Uttar Pradesh can set an example for other states to follow.

Conclusion

The Farmer ID initiative in Uttar Pradesh is much more than an administrative tool; it is a symbol of empowerment and recognition for millions of farmers. By addressing long-standing issues of transparency, inclusivity, and efficiency, Farmer ID can significantly improve the lives of farmers while boosting the state’s agricultural productivity. If implemented effectively, Farmer ID will not only uplift individual farmers but also contribute to India’s vision of doubling farmers’ income and achieving food security. In the years to come, this initiative may well be remembered as a turning point in the modernization of Indian agriculture.

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ARTICLE ID: 04

Ancient Water Harvesting Structures: roadmap to achieve Sustainable Development Goals (SDGs), Climate resilience, and Irrigation water management

Abstract

The water usage from harvested rainwater has more of a past and a future than a significant present. Indeed, the harvesting of rainwater was widely practiced to secure water for drinking, domestic needs, and agricultural production since the beginning of the Neolithic Revolution. Water harvesting has been an integral part of India's rich heritage, deeply rooted in its ancient knowledge systems. The Indian subcontinent has a rich legacy of sustainable water management systems that evolved in response to diverse ecological and cultural contexts. Traditional water harvesting techniques, including stepwells, johads, tanks, and baoris, illustrate indigenous knowledge firmly anchored in sustainability, community engagement, and ecological equilibrium. This article presents an ancient harvesting structure that offers a different perspective on climate adaptation strategies, achieving sustainable development goals, and effective irrigation water management.

Keywords: Ancient harvesting structure, Indian Knowledge System, Sustainable Development, climate resilience, and agriculture productivity.

Introduction

Water is a vital resource for human survival, agriculture, and economic development. India, with its diverse geographical and climatic conditions, has historically faced the challenge of managing water resources. Water conservation, use and management were given considerable importance in ancient India (Shadananan Nair, 2003). India's traditional water harvesting structures are a testament to the creativity and practical wisdom of its people. Based on deep local knowledge and simple engineering skills, communities across the country have made a wide variety of new methods to collect and conserve water suitable to their particular environments. These practices demonstrate a profound understanding of nature and a dedication to sustainable management and traditional tank irrigation. Ancient Indians developed sophisticated systems for water conservation, storage, and distribution, rooted in their understanding of local geography and ecology. The ancient tank structures in South Asia, including those in Dholavira from the Indus Valley Civilization, dating back to around 3,500 BCE, underscore the region's enduring water resources. Numerous tanks and reservoirs were built in India and Sri Lanka during the medieval period. For instance, the Vijayanagara Empire in India (c. 1336 CE to c. 1649 CE) developed extensive tank systems for agriculture and drinking water, illustrating the crucial role of community-managed water resources (Singh, 2008). Water-harvesting systems have been significantly developed in urban and rural areas of some of the most arid and water-stressed regions of the country, such as Kutch and Saurashtra in Gujarat, and Western Rajasthan (Agarwal & Narain, 1997). This article will focus on irrigation water management and its relevance to achieving climate resilience and the SDGs.

Ancient Water Systems: Climate Adaptation and SDG

Water is a critical natural resource for life, development, and the environment. Throughout history, traditional water systems (TWS) have been central to human civilization, with ancient communities thriving along rivers and using innovative water management practices to adapt to climate changes such as droughts and floods. These systems, including reservoirs, dams, canals, and cisterns, reflect a rich heritage of sustainable resource management, blending functionality with cultural significance. Communities in arid and semi-arid regions have developed interconnected systems to manage scarce water resources sustainably over centuries. Despite their historical value, these systems face challenges from climate change, pollution, and urbanization. Rising sea levels, altered precipitation patterns, and societal shifts pose a threat to the integrity of these traditional practices and the ecosystems they support. However, traditional water systems remain relevant today. They offer lessons for addressing contemporary water challenges, including sustainable management, climate adaptation, and community empowerment. Adaptation of these systems in modern contexts includes revival initiatives that combine indigenous knowledge with technologies such as GIS and remote sensing to optimize water resource management and facilitate better climate adaptation. (Gupta et al., 2014).

The 2030 Agenda for Sustainable Development emphasizes the interconnectedness of its 17 SDGs, which collectively address economic, social, and environmental dimensions of sustainability. Goals such as clean water and sanitation (Goal 6), climate action (Goal 13), and life on land (Goal 15) directly align with the principles of TWS. Agenda 21, adopted during the 1992 Rio Earth Summit, recognized the importance of Indigenous communities and local knowledge in managing traditional water systems. Their integration into modern development policies could help achieve the Sustainable Development Goals (SDGs) by promoting food security, reducing poverty, and enhancing environmental sustainability. (UNDP,2015),

Ancient Water Harvesting Systems in India

Water has been harvested in India since ancient times, with our ancestors refining the art of water management. Many water harvesting structures and water conveyance systems have been developed that are specific to the eco-regions and cultures. From open community lands, they collected the rain and stored it in artificial wells. They harvested monsoon runoff by capturing water from swollen streams during the monsoon season and storing it in various forms of water bodies. These systems—such as tanks, stepwells, johads, and cascading reservoirs—not only address immediate agricultural water needs but also recharge groundwater, reduce soil erosion, and support multiple Sustainable Development Goals.

1. Phad,

Phad community-managed irrigation system probably came into existence a few centuries ago. The system starts with a bhandhara (check dam) built across a river, from which kalvas (canals) branch out to carry water into the fields in the phad (agricultural block).

Sandams (escapes outlets) ensure that the excess water is removed from the canals by charis (distributaries) and sarangs (field channels). The Phad system is operated on three rivers in the Tapi basin - Panjhra, Mosam and Aram - in the Dhule and Nasik districts of Maharashtra.

2. Khadins are ingenious constructions designed to harvest surface runoff water for agriculture. The main feature of a khadin, also called a dhora, is a long earthen embankment that is built across the hill slopes of gravelly uplands. Sluices and spillways allow excess

water to drain off, and the water-saturated land can then be used for crop production. First designed by the Paliwal Brahmins of Jaisalmer in the 15th century, this system bears remarkable similarity to the irrigation methods of the ancient people of Ur (present-day Iraq).

3. Ahar Pynes are traditional floodwater harvesting systems indigenous to South Bihar. Ahars are reservoirs with embankments on three sides, built at the end of diversion channels, such as pynes. Pynes are artificial rivulets that divert water from rivers to collect it in the ahars for irrigation during the dry months. Paddy cultivation in this relatively low rainfall area depends mainly on ahar pynes.

4. The Zabo (meaning 'impounding runoff') system combines water conservation with forestry, agriculture, and animal care. Practised in Nagaland, Zabo is also known as the Ruza system. Rainwater that falls on forested hilltops is collected by channels that deposit the runoff water in pond-like structures created on the terraced hillsides. The channels also pass through cattle yards, collecting the dung and urine of animals, before ultimately meandering into paddy fields at the foot of the hill. Ponds created in the paddy

field are then used to rear fish and foster the growth of medicinal plants.

5. Kuhls are surface water channels found in the mountainous regions of Himachal Pradesh. The channels carry glacial waters from rivers and streams into the fields. The Kangra Valley system has an estimated 715 major kuhls and 2,500 minor kuhls that irrigate more than 30,000 hectares in the valley. An important cultural tradition, the kuhls were built either through public donations or by royal rulers. A Kohli would be designated as the master of the kuhl, and he would be responsible for the maintenance of the kuhl.

6. Talab / Bandhis: Talabs are reservoirs. They may be natural, such as the ponds (pokhariyan) at Tikamgarh in the Bundelkhand region. They can be human-made, such as the lakes in Udaipur. A reservoir area of less than five bighas is called a talai; a medium-sized lake is called a bandhi or talab; bigger lakes are called sagar or samand. The Pokhariyan serve irrigation and drinking purposes. When the water in these reservoirs dries up just a few days after the monsoon, the pond beds

are cultivated with rice.

7. Bamboo Drip irrigation System is an ingenious system of efficient water management that has been practised for over two centuries in northeast India. The tribal farmers of the region have developed a system for irrigation in which water from perennial springs is diverted to the terrace fields using varying sizes and shapes of bamboo pipes. Best suited for crops that require less water, the system ensures that small drops of water are delivered directly to the plant's roots. This ancient system is used by farmers in the Khasi and Jaintia hills to drip-irrigate their black pepper cultivation.

(Source: The Better India; CSI)

Impact on agriculture

- In agriculture-dominated villages, there is a change in surface water and groundwater availability.
- Significant economic gains are achieved by taking *rabi* crops.
- Drought mitigations
- prevention of erosion and increased soil moisture.
- Conversion of wasteland into agricultural land.
- Flourish animal husbandry as an allied sector.

(Source: Kumar and Kandpal, 2003)

Conclusion:

Ancient water harvesting structures hold significant importance in providing ecosystem services. Climate change, pollution, and urbanization have altered precipitation patterns and societal shifts, threatening the integrity of these traditional practices. Adaptation of these systems in modern contexts includes revival initiatives, combining indigenous knowledge with technologies such as GIS and remote sensing to optimize water resource management and enable better climate adaptation, ultimately achieving the SDGs.

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EMBRACING THE PILLARS OF ZERO BUDGET NATURAL FARMING : A SUCCESS STORY OF SHRI PARIMAL

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INTRODUCTION

Natural Farming is a chemical free farming, involving livestock integrated natural farming methods and diversified crop systems rooted in the Indian traditional knowledge. It recognises the interdependence of the natural ecosystem amongst soil, water, microbiome, plants, animals, climate and human requirements. Natural Farming is emerging as a sustainable alternative to chemical-based agriculture**.** It is a farming system that works in harmony with nature, where crops are cultivated without synthetic fertilizers, pesticides, or other harmful chemicals. It relies on locally available natural resources such as cow dung, cow urine, compost, and crop residues to maintain soil fertility and plant health. By emphasizing soil health, biodiversity, and low-cost inputs. Natural Farming aims to produce safe, nutritious food while reducing environmental impact and promoting profitable, self-reliant farming.

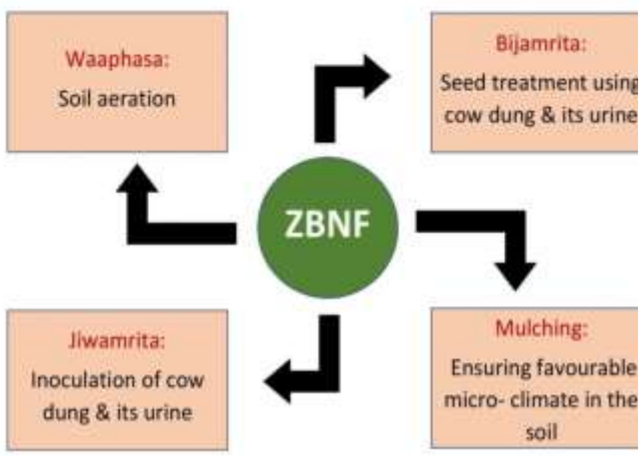
SUBHASH PALEKAR: ZERO BUDGET NATURAL FARMING

Subhash Palekar, a renowned Indian agriculturist, is widely recognized as the father of Zero Budget Natural Farming (ZBNF). In response to the challenges of chemical farming—such as soil degradation, high cultivation costs, and farmer indebtedness—he introduced ZBNF as a practical and sustainable alternative. The concept of "zero budget" refers to farming without relying on expensive external inputs. Instead, it promotes the use of locally available natural resources like cow dung, cow urine, crop residues, jaggery, and pulse flour. Palekar emphasized the importance of **native Indian cows**, as their dung and urine form the foundation for preparing various nutrient-rich formulations in natural farming.

FOUR MAIN PILLARS OF SUBHASH PALEKAR NATURAL FARMING

The four main pillars of Natural Farming are as described below :

1. Jeevamrit (Microbial soil culture)
2. Bijamrit (Seed treatment)
3. Whapasa (Soil moisture management)
4. **Acchadana (Mulchimg)**



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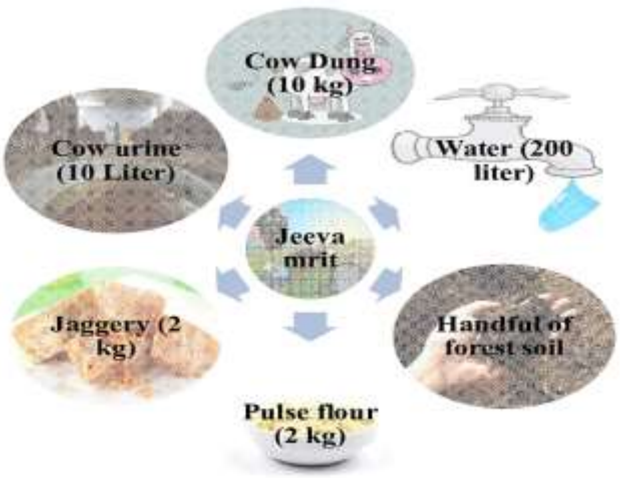
1. **Jeevamrit :**

   It is a fermented microbial culture which provides nutrients, but most importantly, act as a catalytic agent that promotes the activity of microorganisms in the soil as well as increase the population of native earthworms.

Preparation of Jeevamrit :

a. Take 200 litres of water in a barrel
b. Add 10 Kg fresh local cow dung
c. Add 5 to 10 liters aged cow urine
d. Add 2 Kg of Jaggery
e. Add 2 Kg of Pulse flour and
f. Add a handful of soil from the bound of the farm
g. Stir the solution well and let it ferment for 48 hours in the shade.



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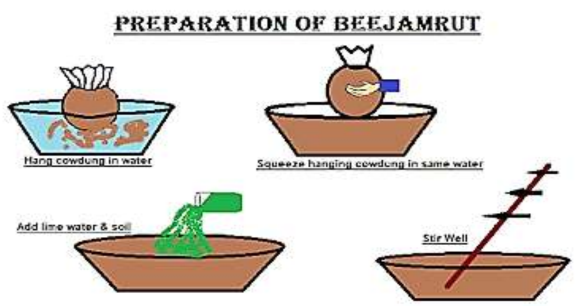
2. **Beejamrit:**

   Beejamrit is particulary used for treatment of seeds, seedlings or any planting material. It is effective in protecting young roots from fungus as well as from soil borne and seed borne diseases that commonly affect plants after the monsoon period.

Preparation of Beejamrut :

a. Take 5 Kg fresh cow dung in a cloth bag and suspend in a container filled with water to extract the soluble ingredients of dung.
b. Suspend 50 g lime in 1 liter water in a separate container.
c. After 12-16 hours squeeze the bag to collect extract and add 5 lit cow urine, 50 gm virgin forest soil, lime water and 20 liters of water.
d. Incubate for 8-12 hours.
e. Filter the contents. The filtrate is used for seed treatment.



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3. **Whapasa**

   It is a condition of maintaining the proper balance of moisture and air in the soil. Instead of waterlogged fields, the soil is kept in a condition where both water and air coexist in the root zone.

4. **Acchadana (Mulching)**

   Acchadana is also known as mulching. It is the practice of covering the soil surface around plants with a layer of natural or organic material. In natural farming, mulching helps to create ideal micro climate for the proper plant growth, increase the water holding capacity as well helps to check the weed population.

CASE STUDY

Shri Parimal, age 35 years, is an experienced farmer who has been practicing Natural Farming long before it gained popularity. After completing his education, he worked as a teacher for several years before deciding to leave his job and take up farming as his main livelihood.

He cultivates crops on his own 1.5 acres of land and an additional 1 acre of leased land. He learned about Natural Farming through the Agricultural Technology Management Agency (ATMA) and has attended several workshops to enhance his knowledge and skills. On his farm, he grows paddy as the main crop, vegetables as intercrops and mango trees along the borders. This intercropping system helps him earn a regular income throughout the year.

Shri Parimal owns two Gir cows and prepares various organic formulations such as Jivamrut**,** Bijamrut **and** Ghan Jivamrut from it. He uses Bijamrut for seed treatment and applies Jivamrut once a month along with irrigation. Occasionally, he uses Neemastra to manage pests and diseases as needed. While his family assists him with certain labour tasks, he hires additional labourers for activities like weeding and harvesting.

He sells his produce weekly in the local market under the brand name "Natural Farming Produce" and also markets it through "Bharat Organic Farm" to several housing associations, in partnership with other farmers. During the last summer season, he earned a net profit of ₹ 1,20,000 per acre.

Being active on social media, Shri Parimal has formed a dedicated customer group where he regularly updates members about the availability of fresh produce. The superior quality and taste of his products help him secure better prices in the market. However, his main concern is that Natural Farming requires more labours and effort as compared to conventional farming methods.

He markets his produce weekly at the local market under the label of "Natural Farming Produce" and also sells through Bharat Organic Farm to several housing associations, in collaboration with fellow farmers. During the last summer season, his net profit from one acre of land was ₹1,20,000.

Active on social media, Shri Parimal has created a group of regular customers to keep them informed about his available produce. The superior quality and taste of his products allow him to command better prices in the market. However, his only concern remains that Natural Farming is relatively more labor-intensive compared to conventional methods.

Farmer Name: Parimalbhai Dalpatbhai Patel

Village : Ranverikalla, Ta. Chikhli. Di. Navsari

CONCLUSION :

It can be concluded that the **four pillars of Natural Farming**, if applied correctly, can serve as a profitable and sustainable alternative to chemical farming. Shri Parimal's story demonstrates that Natural Farming can be successful and sustainable when practiced with dedication and proper knowledge. His transition from teaching to farming shows his commitment to eco-friendly and self-reliant agriculture. By using natural inputs like **Jivamrut** and **Bijamrut**, and combining intercropping with livestock management, he has achieved both high productivity and good income. Additionally, his use of social media and direct marketing has helped him build a loyal customer base and obtain better prices for his produce. Although Natural Farming requires more labour, Shri Parimal's experience proves that it is a viable, profitable and environmentally friendly option for small and medium farmers.

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Protected cultivation of Tomato

What is protected cultivation???

- ✓ Protected cultivation practices can be defined as a cropping technique wherein the micro climate surrounding the plant body is controlled partially or fully as per the requirement of the vegetable species.
- ✓ With the advancement in agriculture various types of protected cultivation practices suitable for a specific type of agro-climatic zone have emerged.
- ✓ It is a potential approach to increase the vegetable production.
- ✓ It involves protection mainly from adverse environmental conditions such as temperature, frost, hails, scorching sun, heavy rains & unusual snow at different production stages.
- ✓ Besides, temperature, relative humidity, wind velocity & soil conditions play major role in the design of protected structures for growing vegetable crops.

Commonly used protected structures

- Poly houses
- Net houses
- Lath houses
- Plastic houses
- Shade houses
- Hot beds
- Cold frames
- Plastic low tunnels

Benefits of protected cultivation

- ✓ Vegetables crops can be grown under unfavorable agro-climatic conditions.
- ✓ Certain vegetable crops can be grown round the year in a particular place.
- ✓ Crop yields can be several times higher than those of under open field conditions.
- ✓ Quality of produce is superior.
- ✓ Higher input use efficiencies are achieved.
- ✓ Management of insect-pests, diseases, weeds, etc. is easier under protection.
- ✓ Agricultural income per unit area increases.
- ✓ It provides an excellent opportunity to produce vegetables for export.
- ✓ Protected structures are ideally suited for production of genetically engineered & micro-propagated vegetable varieties & hybrids.

Protected cultivation of tomato

Introduction

- ✓ Tomato (*Solanum lycopersicum* L.) is the second most important vegetable crops of Peru – Ecuador origin (Rick, 1969) after potato.
- ✓ It's belongs to the family *Solanaceae*. Because of its wider adaptability and versatility, tomato is grown throughout the world either in outdoors or indoors.
- ✓ Among vegetables, tomato is the first crop grown in greenhouse worldwide.
- ✓ Demand for tomatoes is usually strong due to the vine-ripe nature & general overall high level of eating quality.
- ✓ It is universally treated as "**productive**" as well as "**protective food**" having medicinal value, too.
- ✓ As they are high in nutrient contents, they can be used as raw vegetables in sandwiches and salads or it can be processed to several products like puree, paste, soup, powder, juices, ketchup, whole canned fruits etc.

More about tomato

Botanical Name	*Solanum lycopersicum* L.
Other names	Wolf apple, Vilayati Baingan, love apple
Family	Solanaceae
Origin	Peru and Mexico
Ch. No. (2n)	24
Type of fruit	Berry
Cluster of flower	Truss
Seed contains	24% oil
Ancestor of tomato	*Lycopersicum esculentum* var. cerasiforme
Mode of Reproduction	Self-Pollinated
Acid	Citric and Malic
Red Colour	Lycopene
Alkaloid	Tomatine
Toxic compound	Saponine
1st hy. cv. (India)	Karnataka Hybrid (by IAHS from Bangalore) in 1973
Transgenic Varieties	Flavr Savr, Endless Summer, Rosato
Photoperiodism	Day Neutral
Photosynthetically	C3

Types of tomato

Determinate	**Indeterminate**
Main axis ends in a floral bud.	Main axis ends in a Vegetative bud
Main axis ends in a flower cluster. (Nitrogen req. is high) bush type	Main axis does not ends in a flower cluster. (Nitrogen req. is low) veining type
Self topping habit	No self topping habit and growth is continuing.
Does not require staking, training & pruning	Require stacking, training & pruning
At each and every internode inflorescence is there.	At each and every third internode inflorescence is there.
Suitable for open field & mechanized harvesting	Polyhouses
Distance : 75 x 45 cm	90 x 45 cm
Trusses are separated by <3 leaves	Trusses are separated by 3 leaves
Life span short	Life span long
E.g. HS- 101, GT-2, GT-1, AT -3, JT – 3 etc.	E.g. Pusa Ruby, Pusa Divya, Sioux, GT-1, Best Of All, Tip Top, Pant Bahar, Pant T-1, Pant T-3

Which types of tomato suitable for greenhouse condition? Why?

- ✓ Indeterminate type of tomato most suitable for green house condition.
- ✓ For its continuous growth habits and more life cycle.
- ✓ Same time vegetative and reproductive stages occurs.
- ✓ Set new fruit and ripen fruit all at the same time throughout the season.

Soil and Climate

- ✓ Requires relatively warm season and cannot tolerate frost.
- ✓ For plant growth 20-26 ^{0} C temperature is optimum.
- ✓ Lycopene is highest at 21-24 ^{0} C

- ✓ Carotenes develop rapidly at higher temperature.
- ✓ Soil which is well drained, rich in organic matter, with good water holding capacity with pH of 6.0-6.5 is good for tomato cultivation. Sandy loam is best.

Temperature requirements during different growth stages

Growth stage	Temperature (^{0}C)		
	Minimum	Maximum	Optimal
Germination	11	34	16-29
Vegetative growth	18	32	21-24
Fruit setting (night / day)	10 / 18	20 / 30	13-18 /19-24
Formation of lycopene	10	30	21-24
Formation of carotene	10	40	21-32
Optimum relative humidity in glasshouse crops Range from 60- 75%.			

CO_2 concentration

- ✓ High levels (600 to 1000ppm) of carbon dioxide are maintained in the greenhouse atmosphere to increase photosynthesis, growth rate and crop yield.
- ✓ Without the use of the other chemical its increased by closed the greenhouse curtains in the evening (near 4.00 p.m.) and its opening next day after sunrise.
- ✓ Its increased CO_2 concentration and increased ultimately yield.

Preparation of land

- ✓ Soil sterilization
- ✓ Bed preparation
- ✓ Planting distance
- ✓ Mulching
- ✓ Proportion of root media 1:1:1:1 (soil, organic matter, sand and rice husk)

Soil Sterilization

- ✓ By following methods:
- ✓ Fumigation
- ✓ Soil solarisation
- ✓ Steam pasteurization (not in India)
- ✓ **Fumigation**
- ✓ A few chemicals like, Methyl bromide, Chloropicrin (tear gas), Formaldehyde and Hydrogen peroxide are used for fumigation.
- ✓ Formaldehyde is a commonly used chemical to sterilize the root medium.
- ✓ Drenching of root medium with formaldehyde mixed with water 1:10 is the usual practice.
- ✓ After drenching, the soil or root medium will be covered with plastic film. It is found very effective to check the serious problems like damping-off, nematodes etc.
- ✓ For drenching Formalin is used at the rate of 7.5 lit for 100 sq mt *i.e.* 37.5 lit of Formalin will be required for 500 sq. mt polyhouse area.
- ✓ After drenching, planting is done after two weeks, this method is not effective against nematodes and it should not to be used in a standing crop.
- ✓ **Steam Pasteurization**
- ✓ The root medium should be loosened before pasteurization.
- ✓ This will help the movement of steam though the pores and transmit the heat rapidly within the medium.
- ✓ The root medium should not be dry and if dry, addition of water speeds up the rate of pasteurization, though excess watering slows down the speed of pasteurization.
- ✓ Moistening of root medium a week or two prior to pasteurization is the best procedure, which breaks the dormancy of many unmanageable weed seeds, and then pasteurization destroys them easily.
- ✓ **Solarisation**
- ✓ The soil or root medium can be disinfected in warmer climate by covering soil with transparent plastic in hot summer days.

- This will increase the heat of the soil to a great extent and destroy many soil borne pathogens and insects.
- However, solarisation coupled with fumigation works better to control effectively a good number of soil borne insects and diseases.

Bed preparation

- During bed preparation firstly sterilized soils are washed by water to remove the extra chemicals through leaching.
- And open the soil for 2-3 days in sunny period.
- Raised beds of following dimensions are prepared.
- Top width- 90cm
- Height - 40 cm
- Bottom width of bed – 100cm

Mulching

- The mulch reduces evaporation of water from the soil and prevents compaction of the soil surface.
- White (reflective) plastic mulches are recommended to control weeds, converse moisture, reduce humidity and improve light conditions and also to avoid soil contact and prevent diseases.

Seed rate and treatment

- For raising the seedlings in nursery bed 300 - 400 g/ha seeds are required.
- Hybrid seeds are very costly so it should be sown in plug tray, which require only 100-120 g.
- To avoid damping off disease, treat the seed with Tricoderma @ 5-10 g/Kg seed or Carbendazim 2g/Kg seed.

Preparation of seedlings

- The treated seeds are dried in shade for 30 minutes and then sown in the plug tray at the depth of 0.5 cm.
- Spray 19-19-19 along with other micronutrients regularly on alternate days.
- Seedlings are ready for transplanting 4-5 weeks after sowing.

Transplanting time

- Seedlings are ready for transplanting 4-5 weeks after sowing.
- Generally when seedlings attain 5-6 true leaves they are ready for transplanting.

Planting season/ time and method

- Under greenhouse conditions tomato crop can be grown for long duration (10-12 months) by cooling during summer months (April to June or July) and by heating the greenhouse during peak winter months (December and January) in northern parts of the country.

Planting distance

- Determinate type: 90 cm x 60 cm, 90 cm x 45 cm, 75 cm x 45 cm

Steps in plantation of tomato

- Adequate moisture must be available in the soil at the time of plantation.
- The seedlings should be dipped in Bavistin (0.2%) solution at the time of plantation.
- Plantation to be done by making holes or trenches on bed in a zigzag method.
- Planting should be avoided during the hottest period of the day/year & should normally be done during late in the evening.

Care after plantation

- The soil around the plants must be kept humid but not soaking wet.
- Irrigate the plant with hose pipe immediately after plantation.
- During periods with strong sunshine or high temperature, the young plants must frequently be given an over head spray of water to assist establishment & reduce post planting losses.
- For first three weeks the irrigation should be done only by using hose sprayer & later on irrigation should be done by drip system.

Criteria for selection of variety

- High yielding and indeterminate type having resistance/ tolerance to Nematodes, Fusarium Wilt, Verticillium Wilt, TLCV, etc.
- High percentage of number of fruits, freedom from green shoulder, self life and TSS.

- ✓ Consumer preference with respect size, shape and colour.

Varietal selection

- ✓ **Improved Varieties:** Arka Saurabh, Arka Vikas, Arka Ahuti, Arka Ashish, Arka Abha , Arka Alok, HS101, HS102, HS110, Hisar Arun, Hisar Lalima, Hisar Lalit, Hisar Anmol, KS.2, Narendra Tomato 1, Narendra Tomato 2, Pusa Red Plum, Pusa Early Dwarf, Pusa Ruby, Co-1, CO 2, CO 3, S-12, Punjab Chhuhara, PKM 1, Pusa Ruby, Paiyur-1, Shakthi, SL 120, Pusa Gaurav, S 12, Pant Bahar, Pant T3, Solan Gola and Arka Meghali.
- ✓ **F1 Hybrid Varieties:** Arka Abhijit, Arka Shresta, Arka Vishal, Arka Vardan, Pusa Hybrid 1, Pusa Hybrid 2, COTH 1 Hybrid Tomato, Rashmi, Vaishali, Rupali, Naveen, Avinash 2, MTH 4, Sadabahar, Gulmohar and Sonali.

Our university experiment on tomato

- ✓ In which grown a exotic hybrids of tomato.
- ✓ Totally 4 types hybrids grown: two are from Turkey like, 102536 and Pera Dure. Another two are from China like, EG-4121 and EG-4160.
- ✓ In which China hybrids are very susceptible to blight and not well perform.
- ✓ Hybrids of Turkey are resistant to leaf curl virus and well perform in our nature.
- ✓ Dose of the fertilizer were 350:350:350 NPK kg/ha (water soluble, by NCPAH).

Water requirement

- ✓ Now a day's Drip method of irrigation is practiced.
- ✓ Frequent irrigation is essential for plant growth, fruiting and yield.
- ✓ The crop should be irrigated at daily.
- ✓ However during summer more irrigation is required due to higher surface evaporation.
- ✓ Drip system is highly economical and produces quality tomato.

Fertigation

- ✓ After planting, initially given 19:19:19 and 12:61:0 at alternate days up to the flowering time.
- ✓ Flowering time given 13:0:45 and fruiting time given 0:0:52 for the flowers & seed formation.
- ✓ In fertigation time firstly 5-10 minutes given only water and than given the fertilizer solution. (time as per the area).
- ✓ Lastly, 3-5 minutes again given the water because of to washing out the drip.

Fertilizer dose of tomato

- ✓ For variety : 150:100:50 kg of NPK/ha
- ✓ For hybrid : 250:250:250 kg of NPK/ha.
- ✓ South Gujarat : 120:80:70 kg of NPK/ha.
- ✓ By NCPAH: 350:350:350 kg of NPK/ha by water soluble fertilizer

Cultural operation

1. **De-suckering**

- Side shoots (suckers) develop between each compound leaf and stem.
- These suckers are removed, leaving only the main stem as a growing point.
- For this reason, side shoots are usually not pruned until they are few cm long, and can be easily distinguished from the main stem.

2. **Stacking**

- After transplanting immediately plant, stems should be secured to nylon/plastic (high – density) twine, and quality of twine should be ensured.
- Twines are hung from horizontal wires at least 3 m about the ground.
- Horizontal wires must be sturdy enough to support the weight of all plants in the row.

3. **Training**

- Plants should be trained as single (main) stem.
- The plants can be supported with the help of plastic twine loosely anchored around the base of the plants (non slip loop) at one end.
- The same plastic twine is tied to overhead support wires (12 to 16 gauge) running along the length of the row.

- Overhead wires should be at least 3m above the surface of beds and should be firmly anchored to support structures.
- Tie the plant with the help of plastic twine in inclined position to the overhead support wires.
- Twine should be wrapped clockwise around the plant, with complete swirl every three leaves.
- Plastic twine should not be wrapped around fruit clusters. When plants reach the overhead supporting wires, unite the twine and lower the vines and twines at least three feet (once in two weeks).
- After lowering, vines should lean in one direction in one row, vines in extra twine for this purpose when initially tying wines.
- **Training systems:**
- Single stem
- Two stem
- Three stem
- Spacing: 60 x 45 cm (NCPAH)

4. **Topping**

- Six weeks before the anticipated crop termination date, the growing point and small fruit clusters at the top of the plant are removed this operation is called Topping.
- Topping is carried out for rapid fruit development and improving size of already-set fruit in the lower part of the plant.
- To avoid sunburn the shoots are left to grow at the top.

5. **Pollination**

- Although Tomato is highly self pollinated crop, but aided pollination is needed in the greenhouse grown Tomatoes due to limited air movement & high humidity.
- Bumble bees are the perfect pollinator, even under environmental stress conditions like low & high temperature.
- Bee hives are usually active for 6 to 10 weeks where after these should be replaced.
- In electric or battery- powered vibrators, flower clusters are vibrated or shaken for a second or two.
- This method is not effective on cloudy days because the humidity prevents pollen dehiscence even with vibration.
- However, it might be a good idea to pollinate on every sunny day during winter season.
- This practice is done twice a day at 10:00 to 11:00 AM. {Humidity is lower at this time thus facilitating pollen dehiscence}.
- In addition, fruit size seems to be maximized by pollination during these hours.

6. **De leafing**

- When vines are lowered, leaves touching the ground are removed to prevent diseases development.
- The amount of de-leafing that occurs higher up the plant varies between growers.
- The purpose of de-leafing higher up the plant stem is to increase light penetration and air circulation.
- Typically, all leaves are removed below the lowest fruit cluster, which has not been harvested.
- De leafing also helps to make more carbohydrates available to the fruit trusses, thereby increasing yield. This operation is carried out in all types of tomatoes.

7. **Fruit thinning**

- Small, undersized fruit at the end of cluster (distal fruit) are always removed, as these will generally not grow to marketable size and reduces the size of the other fruits on the cluster.
- Specially in Beefsteak tomatoes in initial development, when the plants are young.

Using of growth regulators

- ✓ The growth regulators can be used to increase fruit set at high and low temperature to reduce the leaf curl incidence.
- ✓ The flower dipping in PCPA (Parachloro-Phenoxy acetic acid) 30 ppm at the fully open

stage to increase the fruit set at low and high temperature.

- ✓ The application of Cycocel (500ppm) on the plants in nursery 3-4 days before transplanting another spray of it 25-30 days after transplanting.
- ✓ It reduces the leaf curl incidence.

Other growth regulators are given in table;

Chemicals	**Common name**	**Dose (mg/l**	**Effective**
2-Chloroethylphosponic acid	Ethephon	200- nt spray	Flowering induction, better rooting and setting of plants
2,4 Dichlorophenoxy acetic acid	2,4-D	2-5 as or ray	Increase fruit set, earliness and parthenocarpy
3- Indole Butyric acid	IBA	50-	Increase fruit set
3 Indole acetic acid	IAA	Folia	For good fruit size and yield

Harvesting

- ✓ Harvesting of tomatoes starts after 60-75 days the total crop period.
- ✓ Harvesting is done daily or alternate day depending on market distance and choice.
- ✓ Harvesting at the proper stage of maturity, careful and minimal handling of the produce will help in maintaining better fruit quality and reduce storage losses.
- ✓ Harvesting is generally done during morning and evening hours.
- ✓ Avoid harvesting immediately after fogging to check the disease and pest under control and to maintain better keeping quality of fruit.

Yield

- ✓ Truss tomatoes-25-30 kg/sq.m.
- ✓ Cherry tomatoes-15-20 kg/sq.m
- ✓ Variety : 20-30 ton./ha
- ✓ Hybrid : 60-70 ton./ha

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An overview on Chickpea Breeding at ICAR-Indian Institute of Pulses Research, Kanpur 208024, Uttar Pradesh, India.

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INTRODUCTION

Pulses are very much important food crop not only in India but also whole world because they are the major source of proteins, essential amino acids and minerals in human diet. As above discussed, pulses are the major source of proteins because they contain about 20 to 25% proteins as compared to 6-7% in Rice and 10-12% in other cereal crops that' why pulses keep a good position in global food index. Pulses are important not only nutritional point of view but also, they are more much important as environmental point view because they have some characteristics to stand in field without artificial supply of water or very little demand as their leaves are specially adapted for water saving such as small in size, pubescence and presence of spines on leaves and stems.

Botanically pulses belong to "Leguminosae" or "Fabaceae" family which are self- pollinated in nature excluding "Pigeonpea" (considered as "Often Cross-Pollinated" crop) and they have tap root system, branched and weak stem, compound leaves, complete flower with special arrangement of floral components such as calyx arrange in *Valvate* fashion, corolla in *Vexillary* fashion, anthers in *Diadelphous* condition 9+1 (9 united together and 1free) and ovary with single carpel (Monocarpellary) Superior, Unilocular and Marginal placentation and their seeds are considered as "Dicot" because they have two cotyledons per seed and Non-endospermic in nature. Both, types of germination seen in pulses like "Epigeal"- Urdbean, Mungbean, Pigeonpea and Ricebean etc. and "Hypogeal"- Chickpea, Fieldpea, Lentil, and Lathyrus.

Table-01

S.No.	Crops	Global Scenario					India's Rank
		Area	% Contr.	Production	% Contr.	Yield	
1.	Chickpea	148.11	15	180.95	19	1222	Ist
2.	Pigeonpea	60.30	6	53.27	5	883	Ist
3.	Lentil	55.04	6	66.56	7	1209	IInd
4.	Fieldpea	71.60	7	141.66	15	1979	IVth
5.	Beans Dry	367.92	38	283.46	29	770	Ist
6.	Cowpea	151.91	16	97.75	10	643	-
7.	Others	104.80	11	150.27	15	1434	-
	Total	**959.68**		**973.92**		**1015**	

(**Source**: FAO Stat., 2022.)

The global scenario of pulses production reveals that Chickpea, Pigeonpea, Lentil, Fieldpea and Beans Dry are top most and other pulses with minute contribution in global production of pulses are cultivated about **959.68 lakh ha** with production about **973.92 lakh tones** and with productivity about 1015 kg/ha.

In India during rabi 2021-22 area under chickpea cultivation was 10.91 M ha and production was 13.75 M tones. Maharashtra (25.97%) is leading producer of chickpea followed by Rajasthan (20.65%), Madhya Pradesh (18.59%), Gujrat (10.1%) and Uttar Pradesh (5.64%) with productivity of 12.6 q/ha showed high growth rate in chickpea production in India.

Pulses are consumed directly as food (Dal) and also used in preparation of some special confectionary, pulses flour, Animal feeds, Compost etc. pulses are very helpful in Sustainable Agriculture because they fix atmospheric nitrogen into the soil and make them available for the plants and now their straw are used to make "Eco-friendly" and "Biodegradable" carry bags which is the alternate of polythene.

2.0 Chickpea or Bengal Gram (*Cicer arietinum*):

2.1 Introduction:

Chickpea is the one of the most important pulse crop in India as well as whole world. Chickpea keeps first position in cultivation (148.11 M ha) and also in production (180.95 M Tones). Chickpea shares about 15% area of total pulses cultivation and about 19% production in total pulses production in the world. India is leading producer of chickpea followed by Australia, Turkey, Ethiopia and Pakistan in world chickpea production.

Chickpea is South West Asian origin plant specially from South East Turkey and later spread across whole world. Chickpea belongs to "Leguminosae" or "Fabaceae" family with Scientific name *Cicer arietinum* L. and now days approximately 45 species recognized from whole world in which 1 species is under cultivation and 44 species are wild. Wild species again grouped in to two groups (i) 9 Annual species (ii) 35 are Perennial species. Chickpea originated from one of the wild species consider as progenitor of chickpea is *Cicer reticulatum* L.

Botanically chickpea is a self-pollinated and "Dicot" plant in which tap root system is found that enables to absorb water from deep soil and its leaves are compound, with small pinna favours water saving, stem is moderately weak and branched with bushy growth habit and its height ranges from 45 to 85 cm, flower structure chickpea are following in which five calyx (sepal) arrange in Valvate fashion, Five corolla (petal) arrange in vexillary fashion, 10 anthers in arrange in Diadelphous condition 9+1 (9 united together and 1free) and ovary with single carpel (Monocarpellary) Superior, Unilocular with Marginal placentation, its fruit botanically known as "Pod" generally contains 2 seeds/pod and in special cultivars 3 seeds/pod.

Chickpea is more as nutritional point of view because it contains appx. 23% protein (26.47% in IPC 2005-62, a cultivar released from ICAR-IIPR, Kanpur), 63.5% carbohydrate, 5.3% fat and also rich in minerals like Calcium, Phosphorus, Magnesium, Iron and Zinc. Chickpea is mainly consumed as human food as well as Animal feed. Its, whole grain, Dal, Flour and some other chickpea consumption forms are-Soaked, Sprouted, Fermented, Boiled, Roasted, Salted/Unsalted and fried. Its leaves consumed as vegetable paste. The other part of plant like straw used as fodder. The major use of chickpea crop is restoration of degraded land and in Sustainable Agriculture because they fix atmospheric nitrogen into the soil and make them available for the plants.

3.0 Objectives of Chickpea Breeding:

Chickpea breeding objectives are varied from country wise due do demand of country, in developing countries like India, Turkey, Pakistan, Ethiopia and Syria etc. breeding program moves toward quantity means higher production per unit area but developed countries like, Australia, Canada and United States. Breeding program moves toward quality means production of quality seeds in different aspects like Nutrition.

In Indian institutes like National Research institutes, Central Agricultural Universities, State Agricultural Universities, Deemed Universities and International Agricultural Research institutes (International Crop Research institute for Semi-Arid Tropics, Hyderabad) working on chickpea with different objectives which are described below.

3.1 In the context of ICAR-Indian Institute of Pulses Research, Kanpur-objective of chickpea breeding ***(Genetic enhancement of desi chickpea for higher yield and wider adaptability***) divided into seven ecologies which are described below.

1. ***Breeding for Mechanical Harvestable Varieties:***

In this kind of ecology scientists looking for those plants whose growth habit are erect type (< 70 degree angle between soil surface and plant erectness) and their height should be more than 70 cm. and ground clearance should be more than 30 cm.

2. ***Breeding for Timely Sown Irrigated Varieties:***

In this kind of ecology scientists focus in developing different kind of varieties, which can be sown in first fortnight of November and will harvest up to 20 March with optimum irrigation facilities for chickpea.

3. ***Pre-Breeding for Developing Varieties:***

In this kind of ecology scientists looking for plant ideotype from unadopted and wild plant species and select plants for different characteristics of plant.

4. ***Breeding for Rainfed Cultivated Varieties:***

In this type of ecology plant breeders looking for those plants exhibit several characteristics that help them survive and thrive under water-scarce conditions, including deep root systems, efficient water use, and drought tolerance mechanism and maintain productivity even under stress.

5. ***Breeding for Late Sown Varieties:***

In this kind of ecology scientists focus in developing different kind of cultivars which can be sown in late condition nearby 10 December and complete their life cycle in less time period than normal sown condition chickpea with good productivity.

6. ***Breeding for Kabuli Chickpea Varieties:***

In this ecology scientists working on Kabuli chickpea for their genetic improvement and developing new varieties for cultivation.

7. ***Breeding for Development of "Traits Specific Advance Breeding Lines" :***

In this kind of ecology scientists looking for those characteristics of plant which is consider as specific trait like- High protein content, High yielding ability, Erect growth and 3seeds per pod etc.

8. ***Breeding for Heat Tolerance / Very Late sown condition:***

In this kind of ecology scientists focus in developing different kind of cultivars which can be sown in very late condition nearby 8-12 January and selection made for line showing good pod bearing and such line is considered as "***Heat tolerant/Very late***".

4.0 Breeding Strategy in Chickpea:

As stated earlier, chickpea is a Self-Pollinated crop that's why some breeding approaches of self-pollinated crops such as Mass Selection, Pedigree Selection, Pure line Selection, Back Cross Selection, Single Seed Descent and Bulk Method etc.

Now, At ICAR-Indian Institute of Pulses Research, Kanpur basically working with Pedigree Selection, Pureline Selection, Back Cross Selection and Mass Selection.

1. *Mass Selection:*

In this breeding method 200-2000 plants selected with similar but desirable traits are selected and after harvesting and threshing of selected plants seeds mixed together….Ist Year.

The composited seed planted in Preliminary Yield Trial along with standard checks and phenotype of selected population is critically evaluated……. IInd Year.

Promising selections are evaluated in Coordinated Yield Trials at multiple locations and later after evaluation, entry found outstanding then it will be released as new variety…IIIrd to Vth Year.

In sixth year, seeds are multiplicated and distributed to farmers…… VIth Year.

2. *Pureline Selection:*

In this method of selection breeder interested to select Pureline because "pureline is a single, homozygous self-pollinated plant".

Approx 200-3000 plants selected on the basis of their phenotype…. Ist Year.

Individual Plant progenies are grown and desirable plant selected and undesirable plants rejected……IInd Year.

Desirable/Superior progenies are grown in Preliminary Yield Trial with standard checks and inferior progenies are rejected…. IIIrd Year.

Replicated Yield Trials are conducted at several locations and inferior progenies are rejected. Disease resistance and quality test are done simultaneously….. IVth to VIth Year.

Best progeny is released as new variety and seeds multiplied for distribution to farmers.

3. *Pedigree Selection:*

This is the method of breeding to handle segregating population. In this method purelines selected as parents and crossed them to obtain segregating generations and then selection perform in segregating populations. A normal procedure of pedigree selection is given below.

Fig.1 *Chickpea research farm of ICAR-Indian Institute of Pulses Research, Kanpur*

First of all, selected parents (purelines) planted in crossing blocks and make crosses between them to obtain F_1 generation…… I[st] Year. F_1 generation, 10-30 seed space planted and harvested in bulk…… II[nd] Year. Bulk harvested F_2 generation plants (2,000-10,000 plats) planted in row and again harvested in bulk.

Here, a key point should keep in mind that selection does not perform in F_2 generation because in this generation maximum variation is present…. III[rd] Year.

Bulk harvested F_2 generation plants space planted as F_3 generation and superior plants selected for raising next generation. This step continues upto F_6 or F_7 generations as needed. Population become homozygous and homogenous till F_6 or F_7 generation this population are subjected to trials….IV to VII[th] Year.

List of chickpea varieties developed by ICAR-Indian Institute of Pulses Research, Kanpur

SL	Name of Varieties	Year of release	Potential Yield	Ecology	Recommended Area
1.	DCP 1992-3	1998	20-25 q/ha	Irrigated and Timely sown	North Eastern Plain Zone (CVRC)
2.	IPCK 2002-29 (Shubhra)	2009	20-22 q/ha	Irrigated and Timely sown	Central Zone (CVRC)
3.	IPCK2004-29 (Ujjwal)	2010	20-22 q/ha	Irrigated and Timely sown	Central Zone (CVRC)
4.	IPC 2006-77	2019	20-25 q/ha	Irrigated and Late sown	Central Zone (CVRC)
5.					
6.	IPC2004-1	2020	18-20 q/ha	Irrigated and Timely sown	Central and Bundelkhand Region of Uttar Pradesh (SVRC)
7.	IPC 2004-98	2020	18-20 q/ha	Irrigated and Timely sown	Central and Bundelkhand Region of Uttar Pradesh (SVRC)
8.	IPC 2005-62 (High Protein)	2020	18-20 q/ha	Irrigated and Late sown	Western and Bundelkhand Region of Uttar Pradesh (SVRC)
9.	IPC 2011-112 (Keshav)	2020	20-22 q/ha	Irrigated and Timely sown	Western and Eastern Region of Uttar Pradesh (SVRC)
10.	IPCL 2004-14 (Marker Assisted Selection "MAS-1")	2021	18-20 q/ha	Irrigated and Timely sown	North Western Plain Zone (CVRC)
11.	IPC 2007-28 (Atal)	2021	20-22 q/ha	Irrigated and Late sown	Eastern Region of Uttar Pradesh (SVRC)
12.	IPC2010-134 (Shiva)	2021	22-24 q/ha	Irrigated and Timely sown	Western and Bundelkhand Region of Uttar Pradesh (SVRC)
13.	IPC 2013-163 (Madhav)	2021	22-24 q/ha	Irrigated and Timely sown	North Western Plain Zone (CVRC)
14.	IPCMB 2019-3 (Samriddhi, "Molecular Breeding")	2021	20-22 q/ha	Irrigated and Timely sown	Central Zone (CVRC)
15.	IPC 2010-142 (Kuber)	2022	20-22 q/ha	Irrigated and Timely Sown	Western and Eastern Region of Uttar Pradesh (SVRC)
16.	IPCK 2009-145 (Kanchan)	2023	18-20 q/ha	Irrigated and Timely Sown	Western and Eastern Region of Uttar Pradesh (SVRC)
17.	IPCB 2015-132 (Kundan)	2024	20-22 q/ha	Mechanical Harvestable	North Western Plain Zone (CVRC)
18.	IPC 2012-108 (Krishna)	2024	20-22 q/ha	Irrigated and Timely sown	Central Region Uttar Pradesh (SVRC)
19.	IPC 2017-292 (Kranti)	2024	22-24 q/ha	Rainfed Condition	Central Eastern Madhya Pradesh (SVRC)
20.	IPC 2017-351 (Abha)	2024	20-22 q/ha	Mechanical Harvestable	Madhya Pradesh (SVRC)

F_6 or F_7 generation plants, planted in Preliminary Yield Trial with standard checks for evaluation of yield, quality and disease resistance……. VIIIth Year.

Replicated Yield Trials are conducted at several locations and inferior progenies are rejected. Disease resistance and quality tests are done simultaneously…..IX to XIth Year.

Seed multiplied for distribution to farmers and other Agricultural agencies… XIIth Year.

Back Cross Selection:

This breeding approach is used to correct specific defect of any popular variety like-Nutritional value, Disease resistance and Insect pest resistance. In this method a pureline is selected as doner/non-recurrent parent and another is recipient/recurrent parent (any popular variety with specific defect)

Non-recurrent parent crossed with recurrent to get F_1 progeny and later this F_1 progeny crossed with recurrent parent to get BC_1.

The BC_1 progeny crossed with recurrent parent upto BC_7 to BC_8 with simultaneous selection **(In case of dominant character)**.

The BC_1 progeny crossed with recurrent parent upto BC_7 to BC_8 with alternate selfing for selection **(In case of recessive character)**.

After BC_7 to BC_8, population subjected to different trials for evaluation in Preliminary Yield Trial (PYT) and Coordinated Yield Trials (CVT).

5.0 Achievements

There are many achievements of chickpea breeding program ***(Genetic enhancement of desi chickpea for higher yield and wider adaptability)*** at ICAR-Indian Institute of Pulses Research, Kanpur that increasing the living standard of rural people and also played an important role in Indian economy and food security of our country. Some, varieties developed from ICAR-Indian Institute of Pulses Research, Kanpur, using modern plant breeding approaches (discussed earlier) are described below in the ***Table 02***.

6.0 Future Perspective of Chickpea Breeding:

As discussed above, some achievements of chickpea breeding have acquired that played key role in increasing the living standard of rural people, country's economy, mitigate climate change, mitigate public malnutrition and also important for food security of our Nation.We can fulfil our future needs by developing chickpea varieties with different objectives (Mechanical Harvestable, Nutritious, High Yielding, Climate Smart Crops, Eco-friendly and Biotic & Abiotic Stress Tolerant varieties) through conventional & some advance plant breeding techniques, such as *Genome Editing Technology, Molecular Breeding* and *Marker Assisted Selection etc*.

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SILKWORM REARING – SUMMARY OF KEY STAGES AND MANAGEMENT

Introduction:

Sericulture refers to the practice of rearing silkworms (*Bombyx mori*) for obtaining silk. The larval stage continues for about 26 days and is characterized by four moults, resulting in five instars.

• Young age (Chawki): 1st & 2nd instars (up to 2nd moult).
• Late age: 4th & 5th instars.
• 3rd instar: Intermediate, closer to young age in requirements.

1. Young Age (Chawki) Rearing

Box rearing is done using wooden trays (instead of bamboo trays), lined with paraffin paper and fitted with wet foam pads to control humidity. The trays are stacked for easy handling

Instar	Temperature (°C)	Humidity (%)
1st	27	85–90
2nd	27	85–90
3rd	26	80

Humidity above 90% is undesirable and can be controlled using paraffin covers and wet pads. During young age rearing, dim light of 15–30 Lux, photoperiod of 8 hours light and 16 hours dark is maintained. For feeding, tender mulberry leaves of the Kanva-2 (M5) variety are preferred. During the second larval stage, the 3rd or 4th leaf from the top is selected, and the leaves are cut into small pieces measuring about 0.5–1 cm². Leaves between 4-10 weeks are avoided, and morning-plucked leaves are preferred, stored under wet gunny cloth to maintain freshness. Bed cleaning is performed using the net method with a mesh size of 0.5 cm². During the moulting stage, silkworms are not fed. The rearing room is set to about 70% relative humidity, lime powder is applied at a rate of 30–50 g/m², disturbances are minimized, and adequate ventilation is provided.

2. Late Age Rearing

Instar	Temperature (°C)	Humidity (%)
4th	24–25	75
5th	23–24	70

During late age, dim light of 15–20 Lux with a photoperiod of 16 hours light and 8 hours dark is maintained. The mature mulberry leaves which are thicker, protein-rich, and have less moisture can be fed.

Rearing is carried out on shoot rearing racks measuring 1.2 × 11 m for 50 dfls, arranged in three tiers with 50 cm gaps. Shoots are harvested 60–70 days after pruning, 1 m above the ground, and stored upright in a cool, dark room with 3 cm water at the base. After completing the 3rd instar, the larvae are changed to a new rearing beds. They are fed three times a day during the rainy or winter season and four times a day in summer, using only fresh, tender leaves while avoiding yellow or over-mature ones. Feeding of silkworms can be done either by giving whole leaves or by providing shoots that are cut and placed in trays. The usual feeding schedule is four times a day—at 5 AM, 11 AM, 4 PM, and 10 PM. Bed cleaning is carried out with the help of a rope or net, and proper cleaning and disinfection are done after each transfer. Bed disinfectants such as TNAU Seridust, Resham Jyothi, Vijetha, or Sajeevini are used at the rate of 4 kg per 100 dfls. During the moulting period, paraffin paper is removed, the larvae are evenly spread, adequate ventilation is maintained, and lime powder is used in damp weather to prevent disease.

3. Ripe Worms & Mounting

Ripe worms are identified by a translucent body color indicating an empty gut, noticeable body shrinkage, 4th and 5th segment constrictions, and ceasing of feeding. Once mature, they are transferred to mountages using methods such as hand picking, simultaneous mounting, net mounting, branch mounting, or free mounting. Mountages may be traditional, made from coconut fronds, mango leaves, or straw, or modern, such as chandrikas. The recommended density is 800–900 worms per square meter, with 30–40 chandrikas required for every 100 dfls.

4. Spinning Stage

Maintain relative humidity at 60–70%, moderate light and avoid overcrowding. Use inclined mountages for easy draining of urine. On the second day, remove any larvae that are not spinning, and protect the trays from ants by applying 5% Malathion dust or creating a Lakshman Rekha barrier.

5. Harvesting & Marketing

Cocoons should be harvested on the 5th day after spinning (or the 7th day for bivoltine races), once the pupae have hardened. Amber-colored pupae should be avoided. Dead or diseased larvae should be removed before harvesting. The cocoons are typically marketed on the 6th day (or the 8th day for bivoltine races).

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FARMER`S LIFE INSURANCE: THE 6 WH-QUESTIONS

Abstract

Farmer's life insurance is a protection scheme that provides financial security to the farmer and their family members in case of death or disability. Since farmers often face high risk due to accidents, natural calamities and health issues, life insurance ensures that their dependents are not left helpless. It ensures that no farming household is left vulnerable after the loss of breadwinner. It is a vital tool for social welfare and rural development.

INTRODUCTION:

Farmers are the backbone of the economy, yet they are highly vulnerable to uncertain risks such as accidents, health issues and natural calamities. The sudden death or disability of a farmer can put the entire family into financial distress, as agriculture is often the only source of income. Farmer's life insurance is a social security measure which provides financial protection to the farmer's family giving a lump sum amount in case of death or disability. With low premiums, easy enrolment and government-supported schemes, life insurance ensures that farmer households are not left helpless during difficult times.

1.WHAT IS FARMER'S LIFE INSURANCE?

It is a financial protection scheme that provides security to farmer's families in case of death or disabilities. In short, we can say that farmer's life insurance is a social security program designed to protect farming families from financial hardship when unexpected life risks occur.

2.WHY IS LIFE INSURANCE IMPORTANT TO FARMERS?

Farmer's life insurance is important in many broader ways like:

Financial Protection: If a farmer dies due to accident, illness or natural cause, life insurance provides a lump sum to support the farmer's family to reach daily needs.

Support Children's Education & Family Expenses: The payout ensures continuity of children's education, healthcare and household expenses even after the farmer's death.

Encourages Social Security: Life insurance brings farmers into the formal financial system, ensuring long-term social protection.

Life insurance is important to farmers because it provides security, stability and protection for their families against unexpected life risks.

3.WHO PROVIDES LIFE INSURANCE FOR FARMERS?

Life insurance for farmers is provided by a combination of government schemes, insurance companies and cooperative institutions.

Central Government of India:

- Pradhan Mantri Jeevan Jyothi Bima Yojna (PMJJBY) - Covers death due to any reason.
- Pradhan Mantri Suraksha Bima Yojna (PMSBY) – Covers accidental death and disability.

State Governments:

Some states have special schemes for farmers, for example:

- Rythu Bima (Telangana) - In case of death or disability of the farmer, his/her nominee gets a sum of Rs.5,00,000.
- Chandranna Bima (Andhra Pradesh) – Insurance policy covers Rs.5 lakhs for accidental death and total disability. Rs.2.50 lakhs in case of partial disability.

Life Insurance Corporation of India (LIC): LIC is the major public sector life insurer that implements many government-supported schemes for farmers.

Private Insurance Companies: Private insurers like HDFC Life, ICICI Prudential, Bajaj Allianz, etc., also offer affordable term and life insurance plans suitable for farmers.

Cooperative Banks & Societies: Many cooperative banks, rural banks, and farmer societies help in enrolment and provide group insurance facilities.

4.WHEN CAN FARMERS AVAIL LIFE INSURANCE BENEFITS?

Farmers (or their families) can avail life insurance benefits under many like

- On Death of Farmer: On natural death the nominee receives the assured sum (e.g. under PMJJBY, Rs.2 lakhs is paid). On accidental death coverage can be provided up to Rs.2 lakhs under PMSBY.
- On Disability Due to Accident: Permanent disability leads full insurance up to Rs. 2 lakhs under PMSBY. Partial disability covers up to Rs. 1 lakh under PMSBY.
- During Active Policy Period: Farmers can be covered only when the premium has been paid and the insurance policy is active.

- Under State Schemes: In some states like Telangana families can get coverage anytime after the death of farmer under government schemes.

5.WHERE CAN FARMERS APPLY FOR LIFE INSURANCE?

Farmers can apply for life insurance through several easy channels:

- Banks
- Insurance Companies
- Common Service Centres (CSCs)
- State Government Departments
- Cooperative Societies & Farmer Producer Organizations (FPOs)

6. HOW DO NOMINEES CLAIM BENEFITS AFTER A FARMER'S DEATH?

When a farmer who is insured under a life insurance scheme passes away, the nominee (usually a family member) can claim benefits by following these steps:

➢ Inform the Bank / Insurance Provider -

- The nominee should immediately inform the bank branch, LIC office or insurance company where the farmer was enrolled.
- For state schemes like Rythu Bima , the agriculture/ Revenue Department is informed.

➢ Submit Claim Form –

- A prescribed claim application form must be filled by the nominee.

➢ Provide Required Documents (commonly needed) –

- Death certificate of the farmer
- Aadhaar card / ID proof of nominee
- Bank account details of the nominee (for direct transfer)
- Insurance policy details / enrolment proof
- In case of accidental death (FIR, post-mortem report, hospital records)

➢ Verification –

- Authorities (insurance companies/bank officials/state department) verify the documents.
- Local officials like Tehsildar / Gram Panchayat may certify the claim in state schemes.

➢ Approval & Settlement –

- Once approved, the insurance amount is directly transferred to the nominee's bank amount.
- Timeframe: usually within 15-30 days after submission of valid documents.

CONCLUSION:

Farmer's life insurance plays a vital role in protecting the lives and livelihoods of farming families. It is more just a financial product; it is a tool of social and economic empowerment. It not only provides financial security to the farmer's dependents in times of uncertainty but also ensures stability in agriculture-based households. By covering risks and offering timely benefits, life insurance reduces the economic burden caused by unforeseen events. It encourages farmers to take up agricultural activities with confidence, knowing that their families will not be left vulnerable in their absence. Therefore, it acts as a safety net that provides support to the farmers, strengthens rural communities and contributes to the overall growth of agricultural sector. It is a stepping stone towards building a stronger, more resilient farming community.

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AN OVERVIEW OF DISEASE AND PEST MANAGEMENT IN SILKWORMS

INTRODUCTION

The health of silkworms (*Bombyx mori*) is an important criterion for successful sericulture. However, various pests and diseases including those caused by viruses, bacteria, fungi, protozoa, and insect parasitoid significantly affect larval survival and silk production, highlighting the urgent need for effective integrated management strategies.

1. **Grasserie: (**Causal organism: *Nuclear Polyhedrosis Virus*)

Peak Season: The disease persists throughout the year peaking during summer and rainy seasons

Symptoms: Prior to moulting, the larvae skin looks shiny but fails to shed completely. Infected worms show restless movement along the tray edges, develop swelling of body segments, and their bodies eventually turn yellow.

Source of infection:

Silkworms can become infected via contaminated mulberry leaves, contact with diseased larvae or their body fluids, alternate hosts, and unhygienic rearing conditions. Factors such as higher temperatures, excess humidity, and poor-quality leaves further alleviate disease development.

Management: Disinfect the rearing area and eggs with 0.5% bleaching powder, avoiding tender leaves in late instars, preventing overcrowding, removing diseased larvae, and feeding Amruth as scheduled.

2. **Flacherie: (**Causal organism: *Infectious flacherie Virus*)

Peak Season: April-September.

Symptoms: Infected larvae exhibit loss of appetite, a translucent head and thorax, irregular growth, and body shrinkage. Their gut becomes empty, leading to death from diarrhea often followed by vomiting. The faeces appear soft and watery, sometimes accompanied by rectal protrusion

Management:

- Disinfect the rearing room and equipment using a 0.5% bleaching powder solution and apply Labex.
- Maintain optimal temperature and humidity levels, and provide Amruth feed to help control flacherie.

3. Black Thorax Septicemia: (Causal organism: *Bacillus* spp.)

Peak Season: April-June.

Symptoms: Infected larvae have a swollen body and a darkened thorax region with overall body shrinkage. They excrete soft, watery feces followed by dark brown fluid as decomposition sets in and show sluggish movement with decreased appetite. After death, the thorax turns black, and the infection can spread through wounds caused by rough handling during transfer.

Management: Maintain hygiene, prevent larval injury, avoid overcrowding and faeces buildup, and keep optimum rearing conditions.

4. White Muscardine: (Causal organism: *Beauveria bassiana*)

Peak Season: November to April.

Symptoms: Larvae exhibit moist patches on the skin, show reduced appetite, lethargic movements and may experience vomiting and diarrhea. Later, they become stiff, mummified, covered with white fungal growth with a chalky appearance.

Management:

- Disinfect the rearing room and equipment with 0.5% bleaching powder solution.
- Maintain favourable temperature and avoid high humidity during rearing
- Remove infected larvae from trays before mummification occurs
- Apply fungicides such as 0.6% formalin charff/Labex or Dithane-M45/Captan mixed with kaolin.

5. Pebrine: (Causal organism: *Nosema bombysis*)
Peak Season: Non- seasonal.
Symptoms: Uneven body size, irregular moulting and egg hatching, wrinkled skin, and black pepper-like spots are typical symptoms of infected larvae. Watching under microscope, white pustules containing spores can be seen on the silk glands
Management:

- Clean and disinfect the rearing room and equipment using a 0.5% bleaching powder solution.
- Conduct thorough examination of mother moths and ensure surface sterilization of disease-free layings (dfls)
- Control mulberry pests in the field.
- Feed worms with mulberry leaves sprayed with 3-4% Bavistine.

5. **Uzi fly** (Causal organism: *Exorista bombycis*)

Nature of damage: The uzi fly, is causative for about 10–30% of cocoon loss. The fly lays eggs on the dorsal or dorso-lateral surface of the larvae. After hatching, the maggots enter and feed on the host’s tissues, eventually exiting to pupate and killing the silkworm during the larval or pupal stage

Season of incidence: April to September with peak infestation in wet summer months (July-September).

Management: Integrated approach combining physical, chemical, and biological methods is the best strategy

Physical control:

- Keep fly-proof mesh or nets on ventilators, windows, and doors
- Arrange fly-proof curtains around rearing stands
- Seal floor cracks to block maggot shelter
- Apply china clay dust (3–4 g per 100 worms per m^2) on spinning worms to prevent egg adhesion.
- Frequent Collection and killing of infected maggots, pupae, and infested larvae in hot water
- Drying of cocoons by the 5th day after harvest to kill maggots
- Remove and destroy uzi pupae in markets and reeling units

- Kill adult flies found in rearing houses
- Avoid transporting infested seed cocoons to pest-free areas
- Maintain a 45–60 day rearing holiday between crops
- Use *Uzitrap* to attract and kill adult flies

Chemical control:

Apply a 2% bleaching powder spray on infested worms during the 3rd, 4th, and 5th instar stages to eliminate eggs and safeguard 3–5 kg of cocoons; apply *Uzicide* to larvae for egg destruction.

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The Cochineal Insect : Nature's Source Of Dye

Abstract

The cochineal insect (Dactylopius coccus) , a scale insect native to tropical and subtropical regions is a significant natural source of the carminic acid used to produce carmine dye. This insect has mainly been historically important for textile, food, and cosmetic industries, its eco friendly and long lasting dye properties continue to attract global interest despite the rise of synthetic dyes.

Introduction:

Dactylopiidae, or cochineals, is a family of scale insects that includes only the genus *Dactylopius* and 11 recognized species that are endemic to North and South America An important characteristic of these insects is that they produce carminic acid, probably as a defense mechanism against predation All the species of the genus are considered obligate parasites of Cactacea with high host specificity, particularly for the genera *Nopalea* Salm-Dyck and *Opuntia* Miller.

Because of high ceramic acid concentration of Dactylopius coccus costa, the true cochineal , it is the only species of commercial interest for production. It is reared on opuntia ficus-indica Miller, the cactus pear Carminic acid I s recognized as a natural dye with cosmetic, food, pharmaceutical, textile, and plastic applications . In addition, it is currently used in biomedicine and as a photosynthesizing pigment in solar cells.

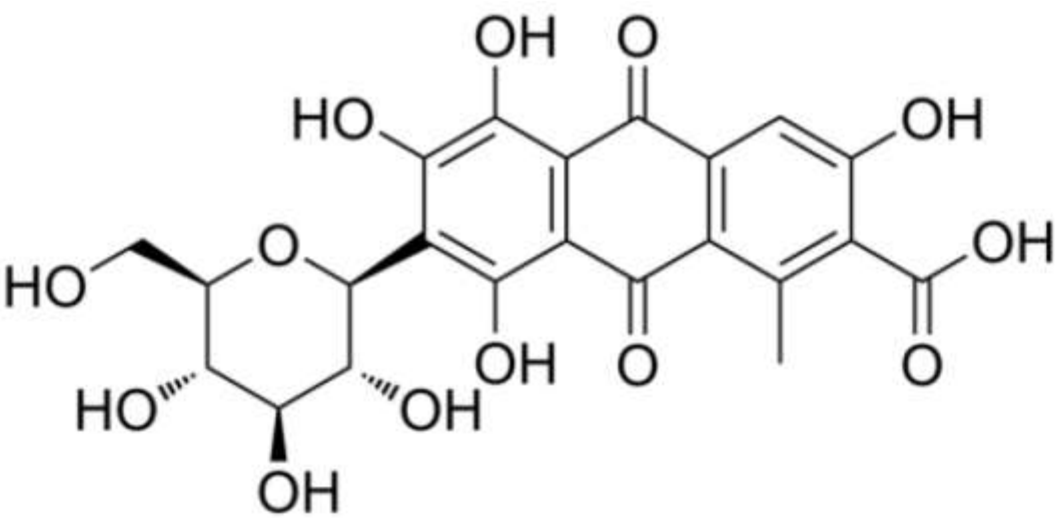

Fig (1): Molecular structure of carminic acid

Wild cochineal (Dactylopius opuntiae Cockerell) has less than 5% carminic acid, so it isn't useful for producing this substance. Instead, it is known as the main pest of prickly pear cactus (*Opuntia ficus-indica*) in commercial farms in Mexico, where both the plant and insect are native. This insect has also spread as an invasive pest to at least 20 countries across the Americas, Europe, Africa, and Asia, where prickly pear was introduced or naturalized and became one of the most widely grown cactus species because of its economic, environmental, and ecological value. Carminic acid is a natural dye obtained from the female insects of Dactylopius coccus costa, a parasite of the prickly pear cactus also known as "grana" . "grana cochinilla fina" and "cochinilla" in Mexico . The molecular structure of CA consists of a polyhydroxylated anthraquinone with a C-glycosil side chain with many hydroxyl moieties, as shown fig(1). Therefore , this dye shows solubility in different media such as water , alcohol ,esters and acidic and alkaline solutions. This dye is a deep red pigment that produces other colour schemes from orange to violet under varying pH.

Carminic acid CA is one of the oldest natural dyes used as a red colorant , it is approved by the FDA and listed in the European Union as additive E120, it means it can be safely used in foods, drinks,medicines,cosmetics and textiles , This is because CA is very stable, both chemically and biologically, studies also show that Ca works as an antioxidant, protecting against free radicals and reactive species.

This insect also contain some other pigments, but these are rarely used. They are mainly analyzed to check for adulteration when making "carmine lake" , which is produced by combining carminic acid with salts like aluminum or calcium.

Extracting natural pigments is not simple because many factors can affect colour quality and stability. Choosing the right extraction method is very important to make the process efficient, cost -effective method and to ensure high pigmented yield. Traditional extraction methods include using solvents,alkaline solutions , centrifugation and other steps . However these methods often take too long, use too much energy and solvents,and give low pigment yields,making them costly and less sustainable.

To overcome these problems new "green" extraction methods are being developed. These include supercritical fluid extraction, microwave assisted extraction (MAE) , ultrasound-assisted extraction (UAE) and high pressure homogenization. These modern methods are more eco-friendly because they reduce the use of harmful solvents,lower energy use shorten ectraction time and increase yield.

- ULTRASOUND-ASSISTED EXTRACTION (UAE): Uses sound waves to create bubbels in the solvent . When the bubbles collapse they push the solvent into the material,improving contact and speeding up pigmented transfer.
- MICROWAVE-ASSISTED EXTRACTION (MAE): Uses microwaves to heat the material diorectly. The energy penetrates inside and heats polar molecules which improves efficiency and reduces processing time.

These two methods , UAE and MAE are especially effective in extracting natural pigments.

The aim of this study was to find the best conditions for using ultrasound and microwave methods to improve pigments yield and efficiency while reducing time. To do this the researchers used a mathematical model to test different conditions like solvent amount ,processing time and temperature . pigments were measured using UV spectrophotometry and the carminic acid molecule was checked with FTIR to make sure it stayed unchanged during process.

BIOLOGY AND LIFE CYCLE:

- Scientific name: Dactylopius coccus.
- Belongs to the family Dactylopiidae .
- Females attach themselves to prickly pear cactus pads (Opuntia species) and feed on plant sap.
- Females secrete carminic acid as a defense mechanism which is later processed into dye.
- The life cycle includes egg,nymoh and adukts stages , with females being wingless and males short-lived with wings.

HISTORICAL SIGNIFICANCE:

Cochineal dye was highly cost by the Azetecs and Mayans. After the Spanish conquest it became major export to Europe used in fabrics, paintings and royal garments.

USES:

1. TEXTILES: Produces carmine dye for brighgt red fabrics.
2. FOOD INDUSTRY: Natural colouring in juices ,jams , candies and dairy products.
3. COSMETICS: Used in lipsticks blush and other beauty products.
4. MEDICINAL VALUE; Traditionally used for antiseptic and healing purposes.

ECONOMICAL AND ENVIRONMENTAL IMPORTANCE:

Still cultivated in peru , Mexico the canary islands and parts of India. Environmentally friendly compared to synthetic dyes which are polluting. Increasing demend for natural dyes boosts its global trade.

CHALLENGES:

- Labor-intensive harvesting process
- Vulnerability to pests and diseases affecting cactus crops.
- Competition from cheaper synthetic dyes.

CONCLUSION:

The cochineal insect is a remarkable natural resource that has shaped cultural , economic . and industrial histories , while its dominance is declined with the introduction of synthetic dyes , the modern preference for eco-freiendly and natural products has revioved its relevance. With sustainable cultivation practices , cochineal production can continue to thrive as a symbol of the balance between tradition and modern industry.

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COCONUT BUTTERMILK: A SUSTAINABLE SOLUTION FOR SOIL REVITALIZATION

Abstract:

In modern agriculture, use of ITK's in farming is very beneficial in controlling pests and diseases. This coconut buttermilk solution,/"Themor Karaisal is a liquid organic fertilizer and pest repellent, prepared by fermenting a mixture of coconut milk or water, buttermilk, and often other organic ingredients like crushed leaves or fruit. This solution enhances plant growth, increases disease resistance, promoting bud growth, enhancing photosynthesis, and providing direct leaf nutrition. And acts as a natural insecticide.

Keywords: Coconut, Buttermilk, plant growth and yield.

Introduction:

Coconut buttermilk solution, an organic fertilizer helps in enhancing plant growth and acts as a biopesticide and biofungicide. It's a sustainable alternative to chemical fertilizers, fungicides and pesticides, utilizing readily available farm resources. This solution has the same growth enhancing potential as that of cytozime/biozyme. It is made by fermenting the coconut water and buttermilk along with grated coconut and waste fruit. Buttermilk is used to protect from fungal diseases like powdery mildew and rust. Coconut water helps in seed development. Waste fruit contains bioactive substances with functional ingredients that have antioxidants. Grated coconut used as soil amendment.

WASTE FRUIT **GRATED COCONUT** **FINAL PRODUCT**

Preparation of coconut buttermilk solution:

S.No	Ingredients	Measurement
1	Sour buttermilk	500 ml
2	Tender Coconut water	100 ml
3	Grated Coconut	½ no
4	Waste fruit	100 g

Procedure:

500ml of Sour buttermilk is added to the container

↓

Then 100ml of tender coconut water or coconut water is added

↓

Both were mixed together

↓

Then add grated coconut of about 25g

↓

Then mix the waste fruit or add it as juice to the mixed solution.

↓

This solution ferments well in seven days.

↓

On the seventh day filter the solution in a bottle and it is used.

Note: The contents of the nylon bag could be reused a few times in subsequent solutions by adding a small quantity of grated coconut every time.

Nutrient content:

These parameters were obtained through analysis of various components in the solution

Sl. No.	PARAMETER	VALUE
1.	Ph	4.39
2.	EC	5.42 dS m^{-1}
3.	Organic carbon	3%
4.	Nitrogen	0.826 %
5.	Phosphorus (P_2O_5)	0.047%
6.	Potassium (K_2O)	0.012 %
7.	Calcium	0.1g
8.	Magnesium	0.05 g
9.	Sulphur	1.744 %

(NOTE: Nutrient content are expressed on moisture free basis)

Application:

- For foliar sparying: mix 50ml of solution in 1 litre of water
- For irrigation: 5 – 10 litres per acre is used.

Effect of coconut buttermilk in crops:

- **Nutrient Content:** Coconut buttermilk is rich in nutrients, including potassium, phosphorus, nitrogen, and micronutrients. These nutrients can enhance soil fertility and promote plant growth.
- **Improved Soil Health:** The application of coconut buttermilk can improve soil structure, increase microbial activity, and enhance organic matter content. This can lead to better water retention and nutrient availability.
- **Crop Yield Increases:** – A study conducted on rice crops showed that the application of coconut buttermilk resulted in a yield increase of approximately 10-20% compared to control groups.

In vegetable crops like tomatoes and cucumbers, farmers have reported yield increases ranging from 15-30% when using coconut buttermilk as a foliar spray or soil drench.

- **Disease Resistance:** Coconut buttermilk has been noted to enhance the disease resistance of certain crops. For instance, it can help reduce the incidence of fungal diseases in plants like tomatoes and peppers.
- **Economic Benefits**: Farmers using coconut buttermilk have reported reduced costs associated with synthetic fertilizers, leading to overall cost savings and increased profitability.

Conclusion:

The adoption of coconut buttermilk solution as an organic farming practice presents a compelling opportunity for the farmers to enhance crop yields, promote plant health and reduce resilience on inorganic fertilizers. As the agriculture sector continues to evolve use of ITK's in farming play a critical role in shaping the future of sustainable farming practices.

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STRESS RESPONSE IN DOMESTIC ANIMALS AND APPROACHES TO MEASURE

What is stress?

The response of the body to any high demand is stress. The response of stress which involves combines activity of the nervous and endocrine systems. There are three stages of biologic Stress:

1. Recognition of an external agent.
2. Adapting the body to amend to the stimuli.
3. Stage of exhaustion when adaptation is lost leading to disease.

If a stressor continues or occurs frequently then deviation of the homeostatic state may result in psychological and physiological pathology. From the viewpoint of domestic animal production, these pathologies may apparent as altered behaviour, diminished immune defence that impacts disease proneness, or altered metabolism that influences either growth, production, or a combination of these responses. Measuring the effect of stress on animal production is difficult because these manifestations may occur at a subclinical level. Rising new precise measures of stress will allow producers to screen variations in animal husbandry or production systems and regulate whether these changes diminish or eradicate the physiological effects of both acute and chronic stress.

Type of stressors: Mainly two type of stressors: Physical stressors and Psychological stressors

- Physical stressors: Thermal stress, Transportation Stress and Feed deficiency
- Psychological Stressors: Maternal separation and weaning, Isolation and mixing and Restraint stress

1. **Thermal stress:** It include both heat and cold stress, biological functions altered in response to thermal stressors are altered feed intake and digestion, compromised reproduction, transformed body weight and growth, decreased milk production, increased mortality, altered metabolic function.
2. **Transportation Stress**: Biological functions altered in response to transportation stressors are increased mortality, increased susceptibility to respiratory disease, increased alkalosis, pulmonary inflammation and mucosal irritation differential leucocyte count and increased in blood cortisol concentration

3. Feed deficiency: Feed deficiency may take place at many levels, comprising precise micronutrients or unbalance intake of protein or energy diet. Biological functions altered in response to feed deficiency stressors are weight loss, behavioural changes, altered metabolic rate, altered blood profile and immune suppression

4. Maternal separation and weaning: It is very potent stressor in infants and young animals. Biological functions altered in response to maternal separation and weaning stressors are increase concentration of norepinephrine and epinephrine, increase acute phase protein in blood, increase heart rate, increase aggressive behaviour, increase ambulation, increase respiratory disease, differential leucocyte count and increased in blood cortisol concentration

5. Isolation and mixing: Isolation or introduction to a new social group can be significant stressors for an individual animal. Biological functions altered in response to maternal separation and social isolation and mixing stressors: altered response to infection, altered heart rate, decreased milk production, increased fear response, altered epithelial tight junctions and mammary gland function, reduced allogrooming and decreased feed access.

6. Restraint stress: Restraint is a collective practice used when handling animal and may have negative effects on productivity. Biological functions altered in response restraint stressors are altered heart rate, altered innate immunity, increased in blood cortisol concentration, increased fear response and increased ACTH

How to measure response in animal: To measure stress response in animal there are two approaches

1. Measuring behavioural Responses to Stress:

Parameters used to measure behavioural responses are entry order, chute scores, pen scores, exit velocity, vocalization, walking, rumination and rope pulling

2. Measuring Physiological Responses to Stress:

Parameters magnificently used to measure physiological responses to stress in cattle are as follow

- Cortisol Measurement: Serum/Plasma, urine, saliva, milk
- Blood Cell Counts: Complete blood count and Neutrophil/Lymphocyte
- Heart rate
- Respiratory rate
- Body Temperature

Changing Approaches to Animal husbandry

1. The management of pain and the stress associated with surgical manipulations, such as castration and dehorning, highlights the increasing concern regarding animal welfare.

2. New technologies, such as immune castration, are being tested to circumvent surgical procedures.

3. Integrated analysis of physiological responses is important to understand the biological consequences of stress response.

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SPACE TECHNOLOGY IN INDIAN AGRICULTURE

Introduction

Agriculture has been the backbone of the Indian economy for centuries. However, this sector faces persistent challenges such as fragmented landholdings, dependency on monsoon rainfall, land degradation, declining soil fertility, pests and diseases, and the impacts of climate change. Addressing these challenges requires innovative approaches that can provide timely, accurate, and scalable solutions. Space technology, particularly remote sensing, geographic information systems (GIS), Global navigation satellite systems (GNSS), and satellite communication, has emerged as a transformative tool in agricultural development. India, through the Indian Space Research Organisation (ISRO), has pioneered the use of satellites for agricultural monitoring, crop forecasting, irrigation management, and rural development. These efforts align with the broader goals of food security, sustainable resource management, and precision farming.

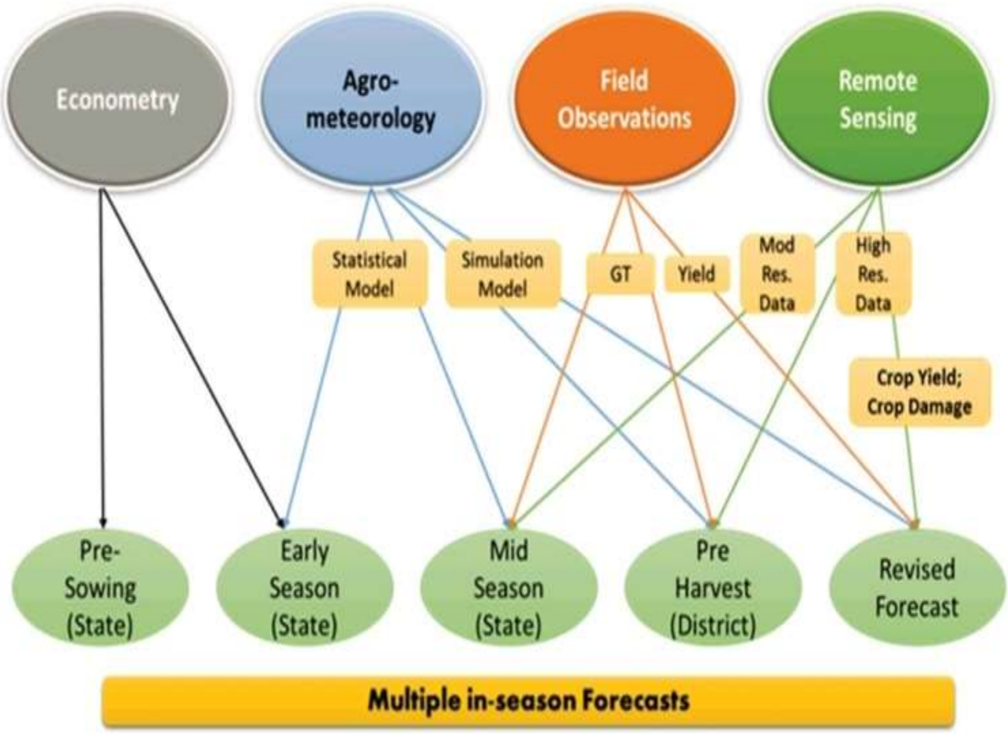

Fig-1. Crop production forecasting approach under FASAL (Source: Ray & Neetu, 2017)

Evolution of Space Technology in Indian Agriculture

India's historical journey of integrating space technology into agriculture began in the 1970s with experimental missions that laid the foundation for operational services. Landmark achievements include the Satellite Instructional Television Experiment (SITE), Launch of Indian Remote Sensing (IRS) satellites, Integrated Mission for Sustainable Development (IMSD), National Natural Resources Management System (NNRMS), National Agricultural Drought Assessment and Monitoring System (NADAMS), Forecasting Agricultural output using Space, Agro-meteorology and Land-based observations (FASAL), and the Coordinated Horticulture Assessment and Management using geo-informatics (CHAMAN). These programs demonstrate how Earth Observation (EO) data from satellites such as IRS, CartoSat, RISAT, and ResourceSat have been systematically employed to generate reliable crop forecasts, monitor droughts and floods, assess land and water resources, and provide actionable advisories to farmers.

Institutional collaboration has been central to these successes. Organizations such as ISRO, the National Remote Sensing Centre (NRSC), the Mahalanobis National Crop Forecast Centre (MNCFC), and state remote sensing centres work in tandem with agricultural research institutions like ICAR and IARI to operationalize space-based agricultural services. Case studies from Punjab, Maharashtra, Odisha, and Andhra Pradesh demonstrate the practical impact of these interventions, from wheat yield mapping to rice acreage estimation and drought early warning systems. In comparison, international programs such as NASA's Earth Observation for Food Security and Agriculture Consortium (EOFSAC), ESA's Sentinel missions, and FAO's GEOGLAM initiative provide complementary insights, highlighting India's global leadership in mainstreaming space applications for agriculture.

Major Applications of Space Technology in Agriculture

Agriculture and Crop Monitoring: Space technology plays a transformative role in agriculture and crop monitoring by providing accurate, timely, and large-scale data that empowers farmers, policymakers, and researchers. Satellite imagery helps estimate sown area, crop type, crop health and yield forecasts. The FASAL project provides pre-harvest estimates of major crops such as wheat, rice, cotton, sugarcane, and oilseeds. This supports government planning for procurement, pricing, and distribution (Fig-1).

Drought Monitoring: The NADAMS program uses satellite data to assess agricultural drought at district and sub-district levels. Similarly,

Soil Health and Land Resource Management: Space technology helps determine suitable land for various crops based on soil and climatic conditions. Satellites like Cartosat and Resourcesat provide data to classify land for agriculture, forestry, urbanization, and conservation. Remote sensing enables mapping of soil types, salinity, erosion-risks, nutrient deficiencies and land degradation. The National Wastelands Monitoring Project uses space data to track changes in degraded lands, enabling reclamation programs for soil fertility management.

Irrigation and Water Resource Management: Space technology supports watershed management, groundwater assessment, and efficient irrigation scheduling. Programs like Accelerated Irrigation Benefit Programme (AIBP) use satellite monitoring to track irrigation infrastructure progress.

Precision Farming and Advisory Services: High-resolution data from satellites combined with GIS and mobile platforms provides customized advice on fertilizer application, pest control, and irrigation. The Kisan Portal and mobile apps supported by ISRO disseminate advisories to farmers.

Agricultural Meteorology: The Agromet Advisory Services (AAS) deliver weather-based advisories using space-based weather observations. Satellites like INSAT provide weather forecasts, helping farmers plan activities like sowing, irrigation, and harvesting. Farmers receive location-specific forecasts on rainfall, temperature, and humidity. Long-term climate data helps develop resilient cropping patterns and stress-tolerant crop varieties.

Disaster Management: Satellites like INSAT and Megha-Tropiques track weather patterns, enabling predictions real-time data on cyclone intensity, trajectory, and landfall points, aiding timely evacuation which enabling farmers to safeguard crops and equipment. Satellites like RISAT detect flood-prone areas, minimizing crop losses by Real-Time Monitoring of Disasters**.** Flood mapping through satellite imagery assists in planning relief measures, insurance claims, and post-disaster recovery. GPS and InSAR (Interferometry Synthetic Aperture Radar) data monitor tectonic movements, identifying seismic hotspots. Satellite data also useful in identification of areas prone to landslides by analyzing slope stability, vegetation, and rainfall.

Crop Forecasting and Policy for Food Security: Accurate yield predictions guide national food storage and distribution policies. Data supports decision-making on crop pricing, exports, and imports.

Crop Insurance: The Pradhan Mantri Fasal Bima Yojana (PMFBY) integrates satellite and drone data for area yield index insurance, reducing disputes and speeding up claim settlement.

Sustainable Agricultural Practices (Green Agriculture): Space technology encourages reduced input usage and promotes green agriculture by organic farming. Monitoring vegetation cover helps track carbon storage and implement sustainable farming techniques. Data obtained by this technology supports conservation practices like crop rotation and cover cropping.

Biodiversity Management: Satellites like Landsat and Sentinel monitor deforestation, afforestation, and changes in forest cover over time. Remote sensing identifies critical habitats, aiding in biodiversity conservation and planning wildlife corridors. Space technology helps track and curb illegal logging and forest encroachments. Monitoring vegetation biomass helps quantify carbon sequestration, essential for climate change mitigation strategies

Renewable energy utilization: Space-based data identifies potential sites for solar, wind, and hydroelectric power generation in rural areas which can very useful for agricultural development.

Poverty Alleviation through Enhanced Livelihood Opportunities: Remote sensing satellites like Resourcesat provide data on soil health, crop conditions, and water resources, enabling precision farming and higher yields. Satellite data supports programs like the Pradhan Mantri Fasal Bima Yojana (PMFBY) by improving the efficiency of crop insurance schemes. Satellite-based identification of Potential Fishing Zones (PFZ) improves catch efficiency, benefiting coastal communities. Space technology aids in sustainable forest management, ensuring resources for tribal communities dependent on forest products.

Skill Development and Employment Generation: Space technology drives growth in sectors like satellite manufacturing, data analytics, and geospatial services, creating high-skilled jobs. Digital platforms supported by satellite connectivity promote e-learning, preparing individuals for jobs in IT, manufacturing, and service sectors. Remote sensing identifies and promotes natural and cultural heritage sites, supporting eco-tourism and generating employment in the hospitality industry.

Challenges and Limitations of Space Technology in Agriculture in India

Despite many remarkable progresses, several challenges limit the full-scale integration of space technology into Indian agriculture. These challenges emerge from technological, infrastructural, institutional, socio-economic, and policy dimensions. Understanding them is critical to designing realistic strategies for the future. Technical limitations are cloud cover, data integration, coarse spatial resolution for smallholder plots, temporal resolution and the need for near real-time data constrain the accuracy and timeliness of information. Socio-economic barriers, including low digital literacy, high costs, and inadequate last-mile connectivity, hinder farmer-level adoption. Institutional issues related to coordination, funding, and open-access data policies also restrict the broader diffusion of benefits. The reliability of space-based applications is sometimes challenged by environmental and ecological complexity i.e. Heterogeneous Cropping Systems (Mixed cropping and intercropping make crop identification from satellites difficult), Weed and Fallow Confusion (Spectral signatures of weeds or fallow lands may resemble those of certain crops, leading to errors), Climate Change Impacts (Extreme weather events like floods or unseasonal rains disrupt the accuracy of forecasting models), etc. Addressing all these barriers requires a multi-pronged approach involving capacity building, policy reforms, farmer training, and enhanced public–private partnerships.

Future Prospects of Space Technology in Indian Agriculture

India's agricultural system is entering a transformative phase, driven by the convergence of space technology, digital tools, and climate-smart practices. Building on decades of satellite-based crop forecasting, drought monitoring, and land-use mapping, the future will focus on precision, integration, and inclusivity. The future of space technology in Indian agriculture lies in the convergence of EO data with artificial intelligence, machine learning, big data analytics, drones, and IoT-enabled sensors. High-resolution nanosatellites, hyperspectral imaging, and cloud-based digital platforms are expected to revolutionize precision agriculture, crop insurance, and climate-smart farming. By focusing in inclusivity, affordability, and farmer-centric service delivery, India can continue to scale its space-based agricultural innovations while also serving as a model for other developing countries.

Conclusion

In conclusion, space technology has already established itself as a critical pillar of India's agricultural development, enabling science-driven policies, resource optimization, sustainable growth, climate resilience and food security. By strengthening institutional frameworks, technological innovation, and farmer empowerment, it promises to further transform Indian agriculture into a more sustainable, productive, and globally competitive sector.

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NEW PARADIGM IN FERTILIZER RECOMMENDATION

INTRODUCTION

Judicious use of fertilizer plays is crucial for enhancing the productivity and sustainability of agroecosystems, while misuse leads to low crop productivity, environmental degradation and wasteful use of resources. A sound fertilizer recommendation is necessary to enhance crop yield and nutrient use efficiency, reduce environmental pollution, improve soil health and sustainability, and save money. Generally, fertilizer applications are based on state recommendations, yield goals, nutrient balance and site and crop-specific needs. The development of sensors, IoT, variable rate technology and automated systems, artificial intelligence and machine learning algorithms, digital platforms, and novel fertilizer materials have advanced fertiliser recommendations. Despite their advantages in applying precise dosage, they also have many drawbacks such as high initial investment, need of skilled personnel,

Fertilizer plays a crucial role in modern intensive agriculture. In 2023-24 alone, Indian agriculture consumes about 35.78 million metric tons of urea, 10.81 million metric tons of DAP, 1.64 million metric tons of MOP, and 11.07 million metric tons of complex fertilizers. Despite being a major consumer of fertilizers globally, its agricultural productivity remains low due to several factors. Major factors include widespread multinutrient deficiencies, imbalanced and inadequate fertilizer usage and inefficient application methods which lead to a significant gap between potential yield and actual yield (Aulakh and Benbi 2008).

Table 1. Impacts of balanced fertilization on crop productivity (kg/ha)

Location	Crop	Control	100%N	100%NP	100%NPK	100%NPK+FYM
Barrackpore	Rice	1450	2958	3040	3159	3432
	Wheat	520	1827	1961	2208	2450
	Jute	972	1808	1916	2254	2531
Pantnagar	Rice	1274	3296	4103	3674	5131
	Wheat	1184	3182	3447	3363	4748
Raipur	Rice	1993	3308	4473	4617	5050
	Wheat	1132	1713	2846	2860	3103
Ludhiana	Maize	1440	3530	4600	5920	6220
	Wheat	1920	3570	4550	5030	5750
Palampur	Maize	807	0	1702	3719	5517
	Wheat	375	0	885	1863	2707
Jabalpur	Soybean	738	824	1444	1638	2016
	Wheat	1334	1744	4265	5463	6279
Ranchi	Soybean	552	438	637	1426	2053
	Wheat	715	855	3419	3259	4302

Source: AICRP on LTFE, ICAR-IISS, Bhopal

To correct these nutrient deficiencies and achieve higher yields, farmers generally apply fertilizers. However, they are applied based on the recommendation of their peers with hardly any scientific recommendation, soil test, crop needs and crop types. Although the Soil Health Card scheme of the Government of India has been considered a success in recommending precise fertilizer rates, a study revealed that only about 48% adhered to the recommended fertilizer applications although 66% were able to understand the recommendations, while 82% of the farmers were aware of the scheme (Reddy 2019). As a result, fertilizer abuse is also a common phenomenon as there is overuse or under-use in our agriculture system. In many parts of the country, farmers continuously apply nitrogen (N) fertilizer particularly urea while omitting phosphorus (P) and potassium (K) fertilizer which has led to acidification, depletion of P and K, while in some soils, excessive application of P fertilizer particularly through DAP by farmers in Punjab leads to P build up. Imbalance fertilization is also noticeable from the deviation of the all-India NPK ratio to 10.9:4.4:1 during 2023-24 from its ideal ratio of 4:2:1 which is considered ideal for sustenance of balanced nutrient supply and accepted for macro-level monitoring (FAI 2024).

Importance of precise fertilizer recommendation

a. Improve crop productivity and nutrient efficiency

Data on crop yield from different long-term experiments (Table 1) showed that balanced nutrient improves crop yield whereas imbalance fertilization or no fertilizer application has a serious detrimental effect on crop productivity. Result from long-term fertilization experiments across various cropping systems and agroecological regions have reported that balanced fertilization improves soil fertility, improves microbial abundance and diversity which have direct or indirect effects on soil health.

b. Reduces environmental pollution

Precise fertilizer recommendation enables judicious use of chemical fertilizers, and minimizes soil degradation and nutrient loss through erosion leaching and runoff, thus safeguarding natural resources and promoting ecological balance.

c. Saves government exchequer

Although the last decade has seen more than 30% growth in the fertilizer sector, from 385.39 lakh metric tonnes in 2014–15 to 503.35 lakh metric tonnes in 2023–24, much of these are highly subsidized to enable the farmers to procure fertilizers at a lower cost than the actual costs. For the 2024 fiscal year alone, India allocated 1.6 trillion rupees (US$20 billion) to fertilizer subsidies. Thus, saving fertilizers through a precise recommendation method would hugely benefit the exchequer.

Common conventional method of fertilizer application

Conventional methods of fertilizer recommendation have been instrumental in guiding agricultural practices to enhance crop yields and maintain soil health. Common approaches followed in India are:

1. General fertilizer recommendations

These are also known as state recommendations as they are given by State Governments based on multi-locational studies using graded N, P, and K fertiliser dosages by assuming that the recommended rate is for soil with medium fertility range. The quantity of fertilizer is either reduced or increased by 25% if the available nutrient range is high or low. These are based on field trials over large areas and expected crop response.

2. Fertilizer application based on target yields

This method uses the already developed crop and site-specific fertilizer equations. The quantity of nutrients required can be obtained by feeding the soil test values and a particular yield that the farmer wants to achieve to the fertilizer equation. This method of nutrient recommendation is based on nutrient contribution from the soil as well as the fertilizer and/or organic fertilizers, and hence is a more sustainable approach than state recommendation.

3. Omission plot technique

It is used to assess the indigenous nutrient-supplying capacity of soils, identification of the limiting nutrient and to determine the specific fertilizer requirements for crops thereby reduces nutrient waste. The indigenous nutrient supply is generally determined by using five treatments such as, control (no fertilizer), NPK, PK (-N), NK (-P) and NP (-K).

4. Diagnosis and Recommendation Integrated System (DRIS)

It is a holistic approach to plant nutrition diagnostics, emphasizing the importance of nutrient balance and interactions by establishing DRIS norms. It guides the formulation of balanced fertilizer programs, optimizing nutrient use efficiency and promoting sustainable agricultural practices especially in perennial crops.

5. **Site-specific nutrient management (SSNM)** It involves balanced nutrient application based on soil test basis, yield goals, and factors influencing crop response to nutrient application to supply the temporal and spatial crop needs. One good example of SSNM Nutrient Expert® software jointly developed by the International Plant Nutrition Institute (IPNI) in collaboration with the International Maize and Wheat Improvement Centre (CIMMYT) to enable end users to make informed decisions about the fertilizer requirement of their crops.

New approaches in fertilizer recommendation

A new paradigm in fertilizer recommendation refers to a shift from conventional, blanket fertilizer applications to a more scientific, data-driven, and crop- and site-specific recommendation utilizing advanced technologies like sensors, plant monitoring, and data analytics to deliver the right amount of nutrients to crops at the optimal time, minimizing environmental impact while maximizing yield.

Sensor-based approach

The sensor-based fertilizer recommendation utilizes advanced real-time monitoring of soil and crop conditions to provide precise and site-specific nutrient management. Such techniques include electrochemical, optical, and radiometric sensors, as well as the deployment of unmanned aerial vehicles (UAVs) and satellite remote sensing (RS) (Zhang et al. 2024). Ion-selective electrode are electrochemical sensors that detect specific molecules and ions, such as NO^{3-}, NO^{2-}, NH^{4+}, PO_4^{3-}, K^+, etc. Optical sensors establish the relationship between spectral characteristics and nutrient concentration in soil or plants. It allows *in situ*, reagent-less, non-destructive and on-line NPK sensing, where instantaneous results can be obtained. For example, Leaf chlorophyll meters, GreenSeeker, SPAD, etc. meters measure leaf chlorophyll concentrations or NDVI in leaves which is considered proportional to the N content in the leaves and used to diagnose nitrogen deficiency in plants. The spectral reflectance of crops and soil, when analyzed across different wavelengths of light, can be used to estimate the nutrient status by identifying specific absorption patterns related to the status of different nutrients and moisture. In recent years, use of UAVs such as drones and RS techniques has gained attention as they enable gathering of data and large scale-monitoring in real-time. Sensors and satellite images can be used to obtain data on crop vigour, soil conditions, and moisture levels at large-scale levels to identify nutrient-deficient areas for targeted fertilizer application.

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PARTICIPATORY RURAL APPRAISAL (PRA) IN AGRICULTURAL EXTENSION: EVOLUTION, IMPORTANCE AND FUTURE PROSPECTS

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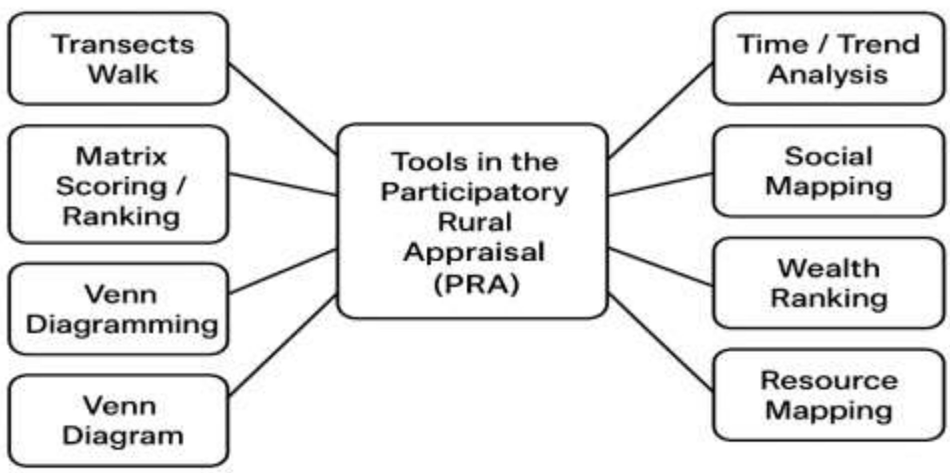
Introduction

Participatory Rural Appraisal (PRA) is a well-established methodology in rural development and agricultural extension that highlights the active participation of local individuals in assessing their own circumstances and strategizing for enhancement. In contrast to conventional top-down approaches, PRA prioritizes empowering farmers and community members to share their insights, articulate their needs and pinpoint suitable solutions to their challenges. It promotes a reciprocal learning experience between extension agents and rural populations, ensuring that development initiatives are grounded in the genuine experiences of the people rather than external presumptions. The underlying philosophy of PRA is based on the conviction that rural inhabitants possess significant knowledge and analytical capabilities regarding their surroundings, resources and livelihood strategies. By involving them through participatory tools and visual techniques, PRA enables extension staff to acquire a more profound comprehension of community dynamics, local obstacles and potential opportunities. This participatory methodology cultivates mutual respect, trust and cooperation, thus rendering agricultural extension more effective, inclusive and sustainable.

Historical Development of PRA

The idea of Participatory Rural Appraisal (PRA) originated in the late 1980s and early 1990s as a reaction to the shortcomings of traditional, top-down development strategies. Previous rural appraisal techniques, such as Rapid Rural Appraisal (RRA), were primarily intended for swift data gathering by external experts. While RRA enhanced efficiency in comparison to prolonged surveys, it still relegated local individuals to the role of mere respondents instead of engaging them as active participants.

Key Tools and Techniques Employed in Participatory Rural Appraisal (PRA)



PRA surfaced as a more inclusive and empowering option. It was championed by development theorists like Robert Chambers and his associates at the Institute of Development Studies (IDS) in the United Kingdom. They advocated for “handing over the stick” representing the shift of control and decision-making from outsiders to local communities. This represented a pivotal transformation in rural development ideology moving from mere information extraction to promoting learning and action. In India, PRA gained traction in the early 1990s through the initiatives of various governmental and non-governmental organizations. Entities such as MYRADA, the National Institute of Rural Development (NIRD) and the Indian Council of Agricultural Research (ICAR) were instrumental in adapting and institutionalizing PRA methodologies for agricultural and community development initiatives. Gradually, PRA evolved into a fundamental component of farmer participatory research, watershed management, rural planning and the design of extension programs, focusing on collective learning and empowerment.

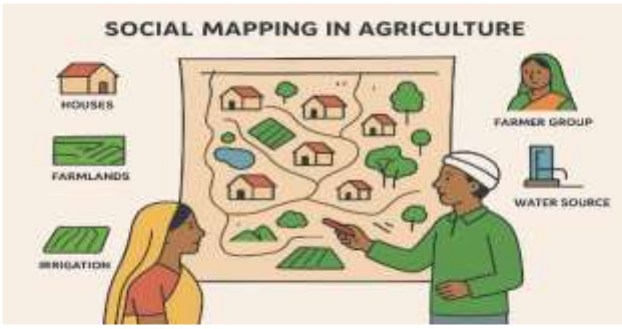
Principles and Core Values of PRA

Participatory Rural Appraisal (PRA) is founded a series of core principles that render it a genuinely participatory and empowering method for rural development. Central to this approach is the principle of community participation and empowerment, which guarantees that local populations, including both men and women, are actively engaged in assessing their own situations, recognizing challenges and devising appropriate solutions. This participatory aspect of PRA enables communities to build confidence, assume responsibility for developmental initiatives and maintain them over time.

Another crucial principle is the importance of learning from local populations. PRA recognizes that rural communities hold a significant amount of indigenous knowledge regarding their environment, agricultural practices and socio-economic conditions. Consequently, extension personnel are encouraged to function as facilitators rather than as experts, drawing insights from the experiences and viewpoints of the communities they assist. This reciprocal learning process enhances the relevance and practicality of agricultural interventions. Flexibility and adaptability are also key characteristics of PRA. In contrast to inflexible survey methodologies, PRA permits facilitators to adjust and integrate tools based on the local context, thereby ensuring greater cultural sensitivity and relevance. This adaptability promotes creativity and inclusiveness during field engagements. Equally significant are the values of sharing and mutual respect, which foster open communication between facilitators and community members. PRA advocates for the exchange of ideas, respect for local customs and collaborative decision-making. The process relies on triangulation, or the application of multiple tools and perspectives to cross-verify information, thus enhancing both accuracy and reliability. Ultimately, PRA highlights a significant transformation in the function of the outsider from simply acting as an investigator to evolving into a facilitator and learner. The core philosophy, frequently referred to as "handing over the stick," signifies that local individuals take charge of the process, while the outsider provides support and gains knowledge from them. Collectively, these principles render PRA a vibrant, inclusive and people-oriented methodology that enhances participatory agricultural extension and rural development initiatives.

Key Tools and Techniques Employed in Participatory Rural Appraisal (PRA)

1. Social Mapping: Social mapping stands out as one of the most commonly used PRA tools. It entails the visual depiction of a village or community, illustrating households, roads, public amenities, schools, water sources, temples, and other significant landmarks. The primary aim is to comprehend the settlement patterns, population distribution, and accessibility to essential services. Local participants create the map on the ground using available materials such as chalk, sticks, colored powders, or seeds. This activity promotes group engagement and aids outsiders in understanding the community’s structure and living conditions.



2. Resource Mapping

Resource mapping serves as a visual instrument for identifying and analyzing the natural, physical, and human resources present in a village. Typically, this map encompasses agricultural lands, irrigation sources, forested areas, grazing lands, rivers, wells, and various soil types. By producing such maps, villagers can evaluate the distribution, utilization, and degradation of resources over time. Furthermore, it acts as a foundation for planning conservation and development projects.

3. Transect Walk

The transect walk is an engaging and observational method where facilitators, farmers, and local residents collaboratively traverse different sections of the village or farmland to observe and discuss land use patterns, cropping systems, soil conditions, water resources, and other local realities. This activity fosters a more profound understanding of spatial variations within the area and aids in identifying site-specific challenges and opportunities. During the walk, participants pause at critical locations, make observations, and document significant issues.

4. Seasonal Calendar / Seasonal Analysis

The seasonal calendar serves as an effective PRA tool that assists communities in examining fluctuations in livelihood activities, climatic conditions, and household well-being throughout the year. It aids in visualizing trends associated with cropping cycles, rainfall, food availability, diseases, labor demand, income, and expenditure. By mapping these seasonal changes, villagers can pinpoint times of stress (such as droughts or food shortages) and devise adaptive strategies.

5. Matrix Ranking and Scoring

Matrix ranking and scoring are participatory techniques that allow villagers to assess and prioritize various options such as crop varieties, technologies, issues, or interventions based on criteria relevant to their local context. Participants arrange the items to be evaluated along one axis and the criteria along the other, subsequently assigning scores according to their preferences. This method offers a structured yet adaptable approach to integrating community preferences into planning.

6. Venn Diagram (Institutional Diagramming)

The Venn diagram, also referred to as institutional diagramming, serves to investigate the relationships among individuals, groups, and organizations within a community. Participants create circles of different sizes to symbolize institutions such as cooperatives, self-help groups, NGOs, panchayats, and government departments. The size of each circle reflects the significance of that institution, while the distance from the central circle (which represents the community) indicates the level of accessibility or influence.

7. Time Line and Trend Analysis

Time line and trend analysis are techniques employed in PRA to document key historical events and transformations that have influenced the community's development. Participants recall and deliberate on important events such as droughts, the introduction of new crops, the establishment of irrigation facilities, or significant policy changes. Trend analysis further investigates patterns in population, yields, rainfall, or employment over time. These methodologies offer valuable perspectives on how the community has progressed and how historical experiences shape current practices.

8. Wealth Ranking

Wealth ranking serves as a socio-economic analysis instrument that organizes households according to their perceived economic standing. Community members establish locally pertinent indicators of wealth, including landholding size, livestock ownership, housing type, and access to credit. Subsequently, they categorize households into classifications such as rich, medium, and poor. This process aids in recognizing disparities within the community and facilitates the effective targeting of development programs.

9. Problem Tree Analysis

Problem tree analysis is employed to uncover the root causes and consequences of significant issues encountered by the community. Participants identify a central problem and then trace its causes (roots) and effects (branches), thereby illustrating its interconnected aspects. This methodology assists in developing realistic and sustainable solutions.

10. Livelihood Analysis

Livelihood analysis seeks to comprehend the various ways in which households sustain their livelihoods through agriculture, wage labor, livestock, or other means. Participants engage in discussions regarding income sources, the extent of reliance on natural resources, and the difficulties encountered in sustaining their livelihoods. This tool is instrumental in identifying vulnerable populations and formulating programs for livelihood diversification.

The Role of PRA in Agricultural Extension

Participatory Rural Appraisal (PRA) is essential for enhancing the effectiveness, inclusivity and relevance of agricultural extension services. By engaging farmers in the evaluation and planning stages, PRA enables extension workers to acquire a comprehensive understanding of local issues, resource availability, cropping systems and livelihood strategies. This insight ensures that interventions and technologies are customized to meet the genuine needs of the community rather than being externally imposed. A significant advantage of PRA in extension is its capacity to boost farmer involvement in decision-making processes. Farmers transition from being mere recipients of information to becoming active collaborators in setting priorities, testing new technologies and assessing results. This participatory method increases the likelihood of adopting improved agricultural practices, as farmers feel more assured and motivated when they are engaged from the outset.

Moreover, PRA enhances communication and fosters trust between extension agents and rural communities. The use of visual aids and interactive activities makes discussions more approachable, especially for illiterate or semi-literate farmers, ensuring that knowledge is disseminated in a significant manner. Additionally, PRA assists extension workers in identifying key stakeholders, influential groups and marginalized communities, thereby promoting equitable and inclusive interventions. Furthermore, PRA encourages bottom-up planning and problem-solving. By empowering communities to examine their own challenges and devise locally relevant solutions, extension programs become more sustainable and tailored to specific contexts. This approach also promotes collective action, as communities frequently collaborate to implement solutions identified through PRA activities. In summary, the incorporation of PRA into agricultural extension shifts the approach from a top-down, prescriptive framework to a collaborative and participatory system. This transformation empowers farmers, enhances the adoption of technology and guarantees that agricultural development initiatives are pertinent, sustainable and driven by the community.

Advantages and Significance of PRA

Participatory Rural Appraisal (PRA) provides a multitude of benefits that render it an essential instrument in agricultural extension and rural development. A primary advantage is the empowerment of rural communities. By involving villagers in the identification of issues, resource analysis and solution planning, PRA cultivates confidence, enhances local leadership and promotes a sense of ownership regarding development initiatives. Moreover, PRA plays a crucial role in fostering inclusivity and social equity. Its participatory techniques guarantee that marginalized groups, such as women, smallholder farmers and tribal communities, are included in decision-making processes. This inclusion results in interventions that more accurately reflect the diverse needs and priorities of the community. Additionally, PRA improves the adoption of technology and sustainability. When farmers participate in the selection, assessment and modification of agricultural practices, they are more inclined to embrace and maintain these innovations. The participatory approach ensures that technologies are suitable for local conditions, economically viable and compatible with existing agricultural systems.

Another significant advantage is enhanced communication and collaboration. PRA tools promote dialogue among farmers, extension agents and other stakeholders, fostering trust and mutual understanding. This collaborative method aids in identifying opportunities for collective action, resource sharing and problem-solving, ultimately bolstering community resilience and development results. Lastly, PRA supports evidence-based and context-specific planning. The visual, adaptable and participatory characteristics of

PRA allow extension personnel to collect reliable data, comprehend local dynamics and devise interventions that are both feasible and sustainable. These advantages establish PRA as a vital approach for contemporary agricultural extension, encouraging development that is responsive, participatory and impactful.

Recent Trends and Future Prospects of PRA

With the rapid advancement of technology and the increasing complexity of agricultural challenges, Participatory Rural Appraisal (PRA) is evolving to meet modern needs. One of the significant trends is the integration of PRA with digital tools and information and communication technology (ICT). Mobile applications, digital mapping and online participatory platforms are now being used to collect, visualize and analyze community data more efficiently, while still maintaining a participatory approach. Another important trend is the application of PRA in climate-smart and sustainable agriculture. PRA methods are being used to identify local climate-related risks, assess resource availability and plan adaptive strategies that are tailored to specific communities. This approach helps farmers develop resilient cropping systems and sustainable livelihood practices.

There is also a growing focus on gender-sensitive and inclusive PRA, ensuring that women, tribal populations and marginalized groups actively participate in decision-making. Extension programs increasingly recognize that empowering these groups leads to better adoption of technologies and improved social equity. Looking forward, PRA is expected to continue evolving as a dynamic, flexible and integrative approach in agricultural extension. Combining traditional participatory techniques with digital innovations, climate resilience planning and inclusive strategies will enhance its relevance and impact. By bridging local knowledge with modern tools, PRA has the potential to transform agricultural extension into a more responsive, participatory and sustainable system.

Conclusion

Participatory Rural Appraisal (PRA) has emerged as a transformative approach in agricultural extension, shifting the focus from top-down interventions to a people-centered, participatory model. By valuing local knowledge, fostering active community engagement and employing flexible visual tools, PRA enables farmers to take part in analyzing problems, prioritizing needs and planning solutions that are practical and sustainable. Its application enhances technology adoption, promotes inclusivity, strengthens communication between extension personnel and rural communities and empowers marginalized groups, including women and tribal populations. While challenges such as time constraints, lack of trained facilitators and institutional barriers remain, careful planning, skillful facilitation and the integration of modern technologies can overcome these limitations. The recent trends of combining PRA with digital tools, climate-smart planning and gender-sensitive approaches indicate a promising future. Overall, PRA continues to be an indispensable tool for modern agricultural extension, ensuring that rural development is participatory, equitable and sustainable.

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ARTICLE ID: 17

STRUCTURAL STABILITY AND YIELD LOSS: A DEEP DIVE INTO RICE CROP LODGING

Introduction:

Crop lodging, a major challenge in agriculture, is the physical collapse of plant canopies due to the plant's structural instability, external forces like strong winds, or a combination of both. This phenomenon is particularly detrimental to Rice (*Oryza sativa* L.), a staple food for billions, as heavy rains and winds can cause significant damage. Lodging primarily affects the upper parts of the plant, where the weight of the developing grains makes it more vulnerable to wind pressure. This collapse manifests in two main forms: root lodging, where the plant is uprooted, and shoot lodging, characterized by the bending of the stem, often at the internodes. The consequences of lodging are severe, leading to reduced grain yield and quality, difficulties in harvesting, and increased post-harvest drying needs.

Types of Lodging:

Lodging in rice can be categorized into three types: culm bending, culm breaking, and root lodging. Culm bending is a common occurrence during crop maturation, often triggered by the weight of heavy panicles or adverse weather. Culm breaking, a more severe form, typically happens at the lower internodes due to excessive pressure. Root lodging, on the other hand, is more common in upland rice or direct-seeded systems where the plant's root system isn't robust enough to anchor it firmly in the soil. Research shows that lodging is most common near harvest time, with rainfall being a significant contributing factor. For example, studies on barley have demonstrated a strong correlation between high rainfall during the grain-filling stage and increased lodging, leading to considerable yield loss. This highlights the importance of understanding the plant traits and weather parameters that contribute to lodging to mitigate its impact.

Factors Influencing Lodging Resistance:

Several factors, both genetic and environmental, determine a rice plant's resistance to lodging. Plant architecture plays a crucial role, with shorter stems generally offering better resistance than taller ones with heavier panicles. Key physical traits that influence susceptibility include plant height, dry weight, basal internodal length, stem diameter, and thickness. The chemical composition of the stem's cell wall, including the concentration of silicon, cellulose, starch, and lignin, is also vital for stem strength. Unfavourable growth conditions can further increase lodging risk.

For instance, heavy nitrogen fertilization, sheath blight infection, and high planting density can lead to the development of weak, long, and thin basal internodes. Environmental factors like wind, rain, soil temperature, and resource competition also contribute to the risk of lodging.

Strategies for Preventing and Mitigating Crop Lodging in Rice:

Preventing and managing crop lodging in rice is essential for maximizing yield and profitability. Tying together is a practice used to prevent or correct crop lodging, which is the bending or breaking of stems that reduces yield and harvesting efficiency (Fig. 1). While methods exist to strengthen rice plants, Tying together is not a common or practical field-wide practice for rice due to the crop's growing conditions. Instead, lodging is prevented through specific agronomic management techniques that promote strong, sturdy culms and deep root systems.

Fig 1: Tying together in rice crop

Conclusion: Farmers can take a proactive approach by selecting short-statured, semi-dwarf rice varieties that have naturally strong stems and deep root systems, making them less susceptible to bending and uprooting. Proper nutrient management is also crucial; instead of applying a large amount of nitrogen at once, farmers should use split applications throughout the growing season and ensure a balanced program that includes potassium and silicon to strengthen cell walls. Managing planting density to prevent overcrowding and ensuring the correct seeding depth can also lead to sturdier, better-anchored plants. In high-yield environments, using plant growth regulators (PGRs) like paclobutrazol can help by shortening and thickening stems, which reduces the plant's vulnerability to wind.

Furthermore, adopting water management techniques like Alternate Wetting and Drying (AWD) encourages the development of a more robust root system. If lodging does occur, the focus shifts to minimizing losses. Farmers should harvest lodged crops as soon as possible to prevent issues like pre-harvest sprouting and disease. Adjusting harvesting techniques, such as cutting against the direction of the lodged plants, can help to pick up fallen crops more effectively. Finally, because lodged crops often have higher moisture content from contact with the soil, immediate moisture management, including the use of grain dryers, is necessary to preserve the quality of the harvested grain and prevent spoilage.

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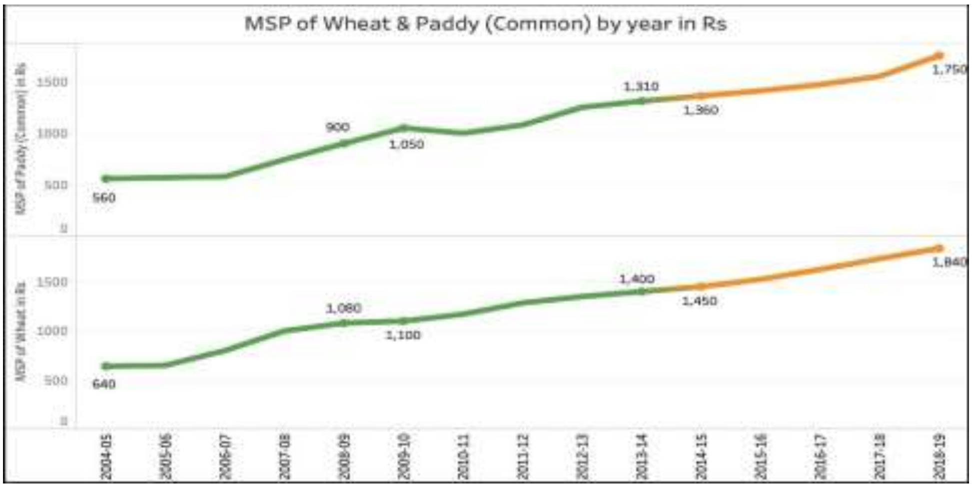
IMPACT OF MINIMUM SUPPORT PRICE (MSP) ON FARMERS IN INDIA

1. Introduction:

The Minimum Support Price (MSP) is a price guarantee announced by the Government of India to protect farmers from sharp declines in agricultural prices. It ensures that farmers receive a fair return on their crops even when market prices are unstable. MSP is currently announced for around 23 major crops, including cereals, pulses, and oilseeds. According to the Extension Journal of Agriculture (Reddy, 2021), MSP plays a critical role in safeguarding farmer incomes and providing stability to the agriculture sector. However, challenges remain in its implementation, including uneven procurement, low awareness among farmers, and regional imbalances.



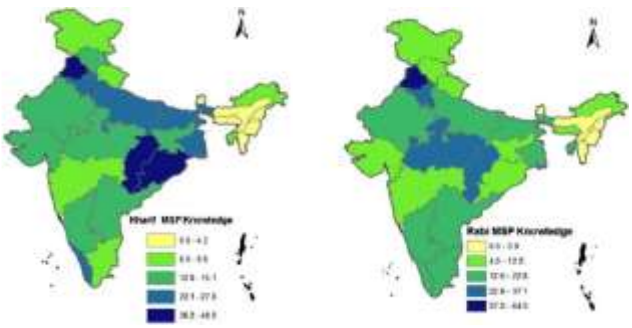
A chat showing MSP trends of wheat and paddy over years.

2. Economics and Production Effects:

MSP has a strong influence on crop production patterns in India. Farmers often prefer cultivating rice and wheat due to assured procurement, resulting in reduced diversification into crops like pulses and oilseeds. As per Paul et al. (2025, ResearchGate), states such as Punjab and Haryana show a high concentration of MSP-supported crops, leading to resource imbalances like groundwater depletion. Additionally, MSP is often set above market prices, contributing to food price inflation (Wikipedia, 2024). Despite its importance, only 20–25% of total wheat and paddy output is procured by the government, leaving the majority of farmers outside its benefits.

Bar graph of MSP procurement percentage across crops.

3.Social and Awareness Challenges: A major issue with MSP is low farmer awareness. Only about one-fourth of farmers are aware of MSP or its procurement mechanisms (farmdocdaily, 2022). Farmers in Punjab and Haryana benefit more due to well-developed procurement centers, while states like Bihar and Odisha lag behind. The Times of India (2023) reported that many farmers are forced to sell below MSP because of lack of storage facilities and delays in government purchases. This uneven access worsens social inequality, particularly affecting small and marginal farmers.



Map showing state-wise MSP awareness levels.

4. Limitations and Alternatives: Although MSP acts as a safety net, it has significant limitations. It promotes the overproduction of water-intensive crops, which leads to soil degradation and groundwater depletion, while also creating a fiscal burden on the government due to high procurement and storage costs (Ideas RePEc, 2021). Alternatives have been proposed, such as the Price Deficiency Payment (PDP) under the PM-AASHA scheme, where farmers receive the difference between MSP and market price without physical procurement. The Swaminathan Committee also recommended fixing MSP at 50% above the cost of production, making it more beneficial for farmers.

Flowchart showing MSP vs Price Deficiency payment system.

5.Conclusion: MSP continues to be an essential tool to shield farmers against price volatility, but its benefits are unevenly distributed. To make MSP more effective, procurement infrastructure should be expanded across all states, farmer awareness must be improved, and diversification towards sustainable crops should be encouraged. Alternatives like PDP and cost-plus MSP calculations can further strengthen farmer welfare. Balancing farmer security with national economic stability will ensure that MSP reforms achieve long-term sustainability.

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THE ORCHID-POLLINATOR CONNECTION: BIOLOGY AND ECOLOGICAL ADAPTATIONS

Abstract

Orchids (family Orchidaceae) represent one of the largest and most diverse groups of flowering plants, encompassing nearly 30,000 species. Their success can be attributed to their highly specialized pollination strategies, unique floral adaptations, and complex ecological relationships. Central to their reproductive biology is the column, a fused structure of the stamens and pistils, which facilitates precise pollination. Orchids employ diverse pollination methods, ranging from nectar rewards to sophisticated deception strategies such as pseudocopulation. The formation of pollinia ensures efficient pollen transfer, often relying on specific pollinators like bees, moths, and wasps. Additionally, orchid seeds, devoid of endosperm, require symbiotic relationships with mycorrhizal fungi for germination. This review explores the biology of orchids, their pollination mechanisms, the role of specialized relationships with pollinators, and their reliance on fungi. By unraveling these complex interactions, this study highlights orchids as a model system for understanding floral evolution and ecological diversity.

Keywords: Adaptation, Floral Biology, Mycorrhizal Fungi, Orchidaceae, Pollination Mechanisms, Pseudocopulation

Introduction

Orchidaceae, the largest family of flowering plants, is characterized by its extraordinary floral diversity and adaptations that facilitate successful pollination. With nearly 30,000 species distributed across various ecosystems, orchids have evolved intricate mechanisms to ensure reproductive success. A hallmark feature of orchids is the fusion of stamens and pistils into a column, enabling precise pollen transfer. This article provides an in-depth exploration of orchid pollination biology, highlighting their unique floral structures, pollination strategies, and ecological interdependencies (Ray and Vendrame 2015).

Unique Floral Biology of Orchids

Orchids possess a distinct floral architecture that sets them apart from other angiosperms. Key features include:

Column Structure: The column is a central structure formed by the fusion of the stamens and pistils. It serves as the primary reproductive apparatus, with the anther situated at the distal end and the stigma located directly beneath it. This arrangement ensures efficient pollen transfer during pollinator visits (Roberts and Dixon 2008).

Labellum (Lip)

A modified petal known as the labellum acts as a landing platform for pollinators. Often brightly colored or patterned, it guides pollinators to the reproductive organs.

Pollinia

Unlike other plants where pollen grains are free, orchids produce pollinia—compact masses of pollen (Fig 1). These structures are covered by a sticky viscidium, ensuring adherence to pollinators and effective pollen transfer (Roberts and Dixon 2008).

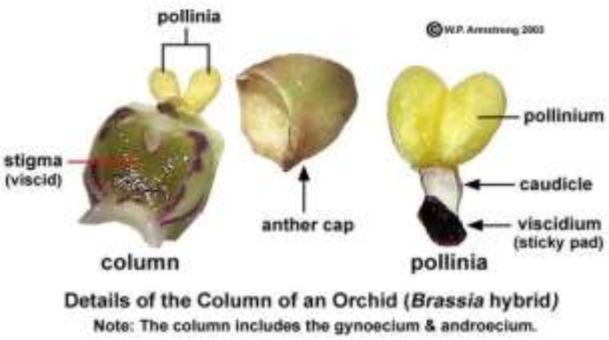

Fig 1: Details of the Column of an Orchid
Note- The column includes the gynoecium and androecium

Seed Germination and Mycorrhizal Associations

Seed Characteristics

Orchid seeds are minute and lack endosperm, the nutritive tissue typically present in seeds. This makes them reliant on external sources for sustenance during germination.

Mycorrhizal Symbiosis

Orchid seeds form symbiotic relationships with mycorrhizal fungi, which provide essential nutrients. The fungi break down complex organic materials in the substrate into simple sugars, which the orchid seedling absorbs (Rasmussen 1995).

- **Epiphytic Orchids:** These orchids primarily utilize fungi during germination, relying on atmospheric nutrients as adults.
- **Terrestrial Orchids:** They maintain prolonged fungal associations throughout their lifecycle.

This dependency highlights the ecological interconnection between orchids and their environment.

Pollination Mechanisms

Orchids exhibit a diverse range of pollination strategies, tailored to specific ecological contexts and pollinators.

Pollinator Diversity

Orchids attract a variety of pollinators, including insects (bees, wasps, moths, flies), birds (hummingbirds), and even snails. The choice of pollinator often influences the floral structure and mechanism of pollen transfer (Scopece *et al*. 2010).

Specialization and Generalization

1. **Specialized Pollination:** Orchids like *Angraecum sesquipedale* rely on specific pollinators such as the African hawkmoth. This precision reduces pollen wastage and enhances reproductive efficiency.

2. **Generalist Pollination:** Some orchids attract multiple pollinator species, increasing the likelihood of pollination but risking reduced specificity in pollen transfer.

Methods of Pollinator Attraction

Rewards

Many orchids produce nectar as a reward for pollinators. For instance, the ghost orchid (*Dendrophylax lindenii*) and Darwin's orchid (*Angraecum sesquipedale*) attract moths with their long nectar spurs, accessible only to species with elongated proboscises (Fig 2).

Deception

Some orchids employ mimicry to deceive pollinators without offering rewards:

- **Pseudocopulation:** Orchids like *Ophrys apifera* mimic the appearance of female bees, enticing male bees to attempt mating. During this process, pollinia attach to the male bee (Fig 3) (Devey 2008).
- **Chemical Mimicry:** *Drakaea* orchids mimic the mating pheromones of female wasps, luring male wasps to their flowers.

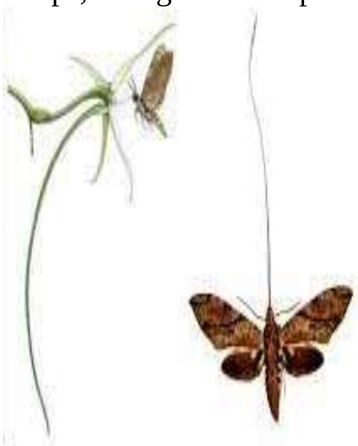

Fig 2: ***Angraecum sesquipedale*** (Darwin's orchid) and African **hawk moth**

Fig 3: Pseudocopulation in *Ophrys apifera* (Bee orchid)

Orchids such as the bucket orchid (*Coryanthes*) use trap mechanisms to ensure pollination. The labellum forms a bucket-like structure filled with fluid, trapping bees. As the bees escape through a narrow exit, they collect or deposit pollinia (Fig 4).

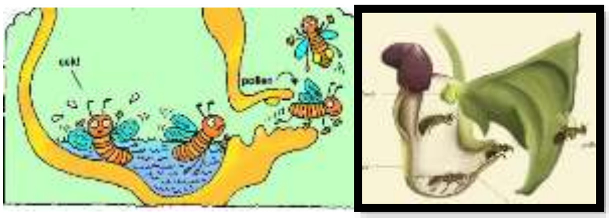

Fig 4: Trap mechanism in Bucket Orchid (*Coryanthes* sps.)

Autogamy and Hand Pollination

Autogamy (Self-Pollination)

Some orchids, like *Dendrobium biflorum*, exhibit autogamy, where pollination occurs without a pollinator. This adaptation ensures reproductive success in environments with scarce pollinators (Ray and Vendrame 2015).

Hand Pollination

In cultivated settings, horticulturists employ hand pollination to overcome the absence of natural pollinators. This meticulous process involves manually transferring pollen from the anther to the stigma using tools like pins.

Conclusion

The pollination biology of orchids is a testament to their evolutionary ingenuity and ecological adaptability. Their reliance on specialized pollinators, unique floral structures, and symbiotic relationships with fungi underscores the intricate interdependencies in nature. While their diverse strategies—ranging from rewards to deception and autogamy—ensure reproductive success, many aspects of orchid-pollinator interactions remain poorly understood. With approximately 30,000 species, orchids offer a fascinating model for studying floral evolution, pollination ecology, and biodiversity. Future research should aim to uncover the pollinators of less-studied orchid species and explore the implications of habitat loss and climate change on their survival.

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WATER CONSERVATION IN AGRICULTURE: NEED OF THE HOUR

Introduction:

Agriculture is the largest consumer of freshwater resource in the world. In India, almost 85% of total freshwater is used in Irrigation. However, due to over-exploitation of groundwater, erratic monsoon, and climatic change, water scarcity has become one of the biggest threats to farming. Many states like Punjab, Haryana, and Uttar Pradesh, once called the "food bowl of India" are now facing declining groundwater tables. If corrective steps are not taken, the future of farming will be at risk. Therefore, water conservation in agriculture is not optional, bot a necessity.

Significance of Water in Agriculture

Basic necessity for crop- Photosynthesis, nutrient transport, and growth all depend on water. Determine productivity- Water availability affects yield, quality, and farmer income. Livestock dependency- Dairy, poultry, and fishes also need water.Socio- economic link – Rural employment, food supply, and export earning all depends on irrigation.

Problems in Current Water Use:

Flood irrigation: Most farmers still follow traditional flood irrigation, where 60–70% of water is wasted due to evaporation and seepage. Over-extraction of groundwater: Tube wells and borewells have lowered groundwater levels drastically. Climate change impact: Droughts in Maharashtra and floods in Bihar show extreme water imbalance. High water-demanding crops: Paddy and sugarcane are grown even in water-scarce regions, worsening the crisis. Inefficient irrigation infrastructure: Canal leakages and poor maintenance cause losses.

Major Water Conservation Methods in Agriculture

1. Rainwater Harvesting

Collecting and storing rainwater for later use in farm ponds, check dams, and percolation tanks. Example: Rajasthan's Johads and Bawris are traditional rainwater harvesting systems. Benefits: Reduces dependency on borewells and improves groundwater recharge.

2. Micro-Irrigation

Drip Irrigation: Supplies water drop by drop directly to plant roots → saves 40–60% water. Sprinkler Irrigation: Sprays water uniformly like rainfall → good for cereals and vegetables. Subsurface Irrigation: Underground pipes to reduce evaporation loss. India's Pradhan Mantri Krishi Sinchai Yojana (PMKSY) promotes micro-irrigation under "More Crop per Drop" slogan.

3. Soil Moisture Conservation Practices

Mulching: Covering soil with crop residues, straw, or plastic sheets reduces evaporation. Conservation tillage/Zero tillage: Less soil disturbance, more water retention. Contour farming and bunding: Reduces runoff on slopes. Green manuring: Improves soil organic matter and moisture-holding capacity.

4. Efficient Crop Planning

Grow drought-tolerant and short-duration crops in dry areas. Promote crop diversification instead of over-reliance on paddy or sugarcane. Integrated Farming Systems (IFS): Combining crops, livestock, and fisheries for better water use efficiency.

5. Traditional Water Conservation Practices

Step wells in Gujarat, tank irrigation in Tamil Nadu, and Zabo system in Nagaland are indigenous methods. Blending modern science with traditional wisdom ensures sustainable solutions.

Benefits of Water Conservation in Agriculture

Higher productivity with less water input. Reduced cost of irrigation for farmers. Prevents soil erosion and salinity caused by over-irrigation. Improves groundwater recharge. Supports sustainable farming and climate resilience. Helps achieve SDG Goal 6: Clean Water and Sanitation and Goal 2: Zero Hunger.

Government Initiatives in India

Pradhan Mantri Krishi Sinchai Yojana (PMKSY) – Focus on Har Khet Ko Pani (water for every field) and More Crop per Drop. National Mission on Micro Irrigation (NMMI) – Subsidies for drip and sprinkler irrigation. Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) – Used for construction of farm ponds and check dams. Jal Shakti Abhiyan – Nationwide campaign for water conservation. Atal Bhujal Yojana – Promotes community groundwater management.

Real-Life Success Stories

Hiware Bazar, Maharashtra – A drought-prone village transformed into a water-rich area through watershed management. Pani Panchayats in Odisha – Farmers collectively manage water resources for equitable distribution. Israel's Model of Drip Irrigation – Despite desert conditions, Israel is a global leader in water-efficient agriculture.

Modern Technologies for Water Conservation

Technological advancement plays a crucial role in reducing water wastage in agriculture. Some modern methods include: Drip Irrigation – Water is delivered directly to the root zone, reducing evaporation losses. Sprinkler Irrigation – Provides uniform water distribution across fields with minimal wastage. Laser Land Leveling – Ensures even leveling of fields, preventing waterlogging and reducing water requirement by 20–25%. Rainwater Harvesting – Collection and storage of rainwater for irrigation, especially in arid and semi-arid regions. Soil Moisture Sensors – Help in monitoring soil water content so that irrigation is applied only when necessary. Use of Drought-Resistant Crop Varieties – These require less water and can survive in water-scarce conditions.

Role of Farmers and Communities

While policies and technologies are essential, the role of farmers and rural communities is equally significant. Traditional water harvesting methods like johads, tanks, check dams, and baolis still play an important role in rural India. Community-based water management, where farmers collectively manage water resources, has shown success in several regions. Farmers are also encouraged to practice crop diversification by growing less water-intensive crops like millets, pulses, and oilseeds instead of paddy or sugarcane in water-scarce areas.

Challenges in Water Conservation

Despite efforts, many challenges remain in achieving sustainable water use in agriculture: Over-dependence on groundwater: Tube wells and bore wells have caused depletion of aquifers. Free or subsidized electricity: This often leads to excessive pumping of groundwater. Preference for water-intensive crops: Farmers continue to grow paddy and sugarcane even in drought-prone regions due to assured procurement and better prices. Climate change: Erratic rainfall, rising temperatures, and frequent droughts add more pressure on water resources. Awareness gap: Many farmers are still unaware of modern water-saving techniques or lack access to resources.

Integrated Water Management Approaches

To achieve long-term sustainability, Integrated Water Resource Management (IWRM) is gaining importance. This approach ensures that water use in agriculture is planned in harmony with domestic, industrial, and ecological needs. Watershed management programs, which combine soil conservation, afforestation, and rainwater harvesting, are effective examples of integrated approaches. By focusing on entire landscapes rather than isolated farms, IWRM ensures equitable water distribution and reduces conflicts between users.

Role of Crop Planning in Water Conservation

Another powerful tool for saving water is scientific crop planning. Selecting the right crop for the right season and region can drastically reduce water demand. For example, shifting from paddy to millets in dry regions can save thousands of liters of water per hectare. Similarly, crop rotation with legumes improves soil health and moisture retention, reducing the need for frequent irrigation. In Punjab and Haryana, campaigns have been launched to promote maize, pulses, and oilseeds in place of water-guzzling rice.

International Experiences in Water Conservation

Learning from global examples can inspire better practices in India:

Israel: Known for its arid climate, Israel has become a global leader in water-efficient agriculture. The country uses precision irrigation technologies, recycling nearly 90% of its wastewater for farming. Australia: Faced with recurring droughts, Australia adopted strict water management laws and encouraged farmers to invest in advanced irrigation systems.China:

Climate Change and Water Conservation

Climate change is expected to intensify both floods and droughts, making water conservation even more urgent. Increasing temperatures accelerate crop water demand, while erratic rainfall affects groundwater recharge. To address this, farmers must adopt climate-smart agriculture practices such as: Conservation tillage to reduce evaporation losses. Use of organic mulches to preserve soil moisture. Agroforestry to provide shade and reduce evapotranspiration.. Climate-smart water management not only secures productivity but also builds resilience against natural disasters.

Public–Private Partnerships in Water Conservation

Private companies and NGOs are also playing a role in promoting water efficiency. Several corporate social responsibility (CSR) programs focus on watershed development, check dam construction, and farmer training. Public–private partnerships can bring investment, technology, and expertise to rural areas where government resources are limited. For example, PepsiCo and Jain Irrigation have worked with farmers to promote drip irrigation in potato and tomato cultivation.

A Vision for the Future

If India aims to ensure food security for its projected population of 1.7 billion by 2050, water must be managed as carefully as land. A future-ready agricultural system will be one that: Uses every drop efficiently. Diversifies crops to match water availability. Revives traditional wisdom while adopting modern science. Encourages community participation and strong policies. Ultimately, water conservation in agriculture is not just about farming—it is about ensuring livelihoods, ecosystems, and national security.

Conclusion

Water is the lifeline of agriculture and food security. With the growing population and changing climate, the pressure on water resources is increasing. Agriculture, being the largest consumer of freshwater, must adopt sustainable practices for its own survival and for the benefit of future generations. Through a combination of government support, modern technologies, community participation, and responsible farming practices, India can overcome the water crisis. Conservation of every drop of water is not just a necessity, but the need of the hour to ensure resilient agriculture and a secure future.

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COLOURED BELL PEPPERS: FROM GREEN TO GORGEOUS

Introduction

Bell peppers, also known as capsicum or *Shimla Mirch*, have long been valued in Indian kitchens for their crisp texture and versatile flavour. While the familiar green pepper dominates local markets, the arrival of vibrant coloured bell peppers, red, yellow, orange and the lesser-known purple, has transformed consumer choices. These coloured variants are not only visually striking but also nutritionally superior and highly profitable for farmers, especially when cultivated under protected structures such as polyhouses, greenhouses and shade nets. Once confined to the shelves of gourmet stores and five-star restaurants, coloured bell peppers are now becoming accessible to a wider audience in Indian cities, symbolising both changing diets and the rise of high-value horticulture.

Table 1. Nutritional highlights of coloured bell peppers.

Colour	Key nutrients and compounds	Health benefits
Red	High in vitamin C, β-carotene and lycopene	Improves immunity, supports eye and skin health, protects against chronic diseases
Yellow	Rich in lutein and vitamin C	Promotes healthy vision, acts as a strong antioxidant, delays ageing effects
Orange	Contains zeaxanthin, carotenoids and vitamin A	Protects eyes from oxidative stress, supports heart health, enhances immunity
Purple	Abundant in anthocyanins and moderate vitamin C	Anti-inflammatory, supports brain and heart health, combats free radicals
Green (immature stage)	Good source of dietary fibre and vitamin K	Aids digestion, supports bone health, provides a low-calorie energy source

Fig. 1. Red (Left), yellow (Middle) and purple (Right) bell peppers growing on plants.

The science of growing colours

Unlike traditional green peppers, coloured bell peppers require more precise cultivation practices. They are best grown in protected structures, where temperature, humidity and light are carefully managed. The optimal daytime temperature for their growth ranges between 20-28 °C, while night temperatures should stay between 16-18 °C. Such controlled conditions are difficult to achieve in open fields, particularly in India's variable climate, which is why polyhouses are widely adopted for bell pepper production. Also, exposure to high temperatures, strong sunlight and heavy rains in the open field often results in poor fruit set, irregular shape, pest incidence and uneven colour development. Inside protected structures, farmers can maintain an ideal microclimate that ensures proper growth, high productivity and superior fruit quality.

Cultivation begins with high-quality hybrid seeds, which are raised in protrays filled with a sterile medium. The seedlings are transplanted into the polyhouse after about 30-35 days, at a spacing of 45-60 cm between plants. Proper spacing allows optimum light penetration (critical for uniform colour development) and air circulation, while drip irrigation and fertigation systems provide precise water and nutrient management, ensuring steady growth and uniform fruiting. Plants are trained vertically on trellis systems and pruning ensures that energy is directed toward fruit production rather than excessive foliage. One remarkable feature of coloured bell peppers is that the fruits start green and only later develop into their final shade after a long period of maturity. Purple peppers, however, are unique as they develop their colour earlier in the maturation process due to the presence of anthocyanins.

Nutritional treasure in every bite

Coloured bell peppers are not just about aesthetics; they are a powerhouse of nutrition. Compared to their green counterparts, they contain higher levels of vitamin C, carotenoids, flavonoids and antioxidants. Each colour variant offers distinct health benefits. Collectively, coloured bell peppers are low in calories (approximately 20-25 kcal per 100 g), making them ideal for weight management. The combination of crunch, sweetness and nutrition has made coloured bell peppers a favourite among health enthusiasts, nutritionists and chefs.

Rising market demand and consumer preference

In recent years, the demand for coloured bell peppers in India has surged, particularly in urban centres such as Delhi, Mumbai, Bengaluru and Hyderabad, reflecting broader changes in food preferences and lifestyles. Their bright appearance makes them a favourite in pizzas, pastas and gourmet dishes, while their nutritional appeal has captured the attention of health-conscious consumers. Purple bell peppers, though relatively rare, are gaining popularity in niche markets and among premium restaurants due to their novelty and exotic appeal. Hotels and restaurants are willing to pay higher prices for these rare variants, creating an emerging market opportunity for growers.

Retail infrastructure has also played a key role. Supermarkets and online grocery platforms prominently display these peppers, attracting health-conscious buyers. Export opportunities are opening up as well, with India supplying coloured bell peppers to Middle Eastern and South Asian markets. For both domestic and export buyers, glossy, thick-fleshed and uniformly coloured fruits are the most sought-after, making greenhouse-grown produce highly competitive. Prices remain strong, often ranging between ₹120 and ₹150 per kg in Indian metropolitan cities, significantly higher than standard green bell peppers.

Fig. 2. Different coloured bell peppers displayed in a supermarket.

Economics of cultivation

Coloured bell pepper production is one of the most profitable ventures in modern horticulture, though it requires a significant initial investment. A naturally ventilated polyhouse suitable for one acre of land can cost around ₹30-40 lakhs (approx. ₹700-1,000 per m^2), depending on the type of structure and equipment installed, including drip irrigation and fertigation systems. Hybrid seeds, fertilisers, plant protection and labour add another ₹6-7 lakhs per acre per season.

While these figures may seem scary, the returns make the venture attractive to progressive farmers. Under protected conditions, yields average around 80-120 t/ha per year under, which is significantly higher than open-field production. Market prices vary depending on colour and season: green bell peppers typically fetch ₹20-30 per kg, while red, yellow, orange and especially purple ones can command premium prices ranging between ₹80 and ₹150 per kg in metropolitan markets. With a conservative market price of ₹120 per kg, farmers can generate gross returns of ₹35-50 lakhs per acre annually. After deducting operational costs, net profits of ₹20-25 lakhs are available, especially after recovering the initial investment within 2-3 years.

Many state government s provide subsidies of around 40-50% on polyhouse constructions under schemes like the National Horticulture Mission (NHM), further reducing financial burdens and making coloured bell pepper farming feasible for small and medium-scale growers.

Challenges and future prospects

Despite its profitability, coloured bell pepper cultivation poses challenges. The cost of setting up a polyhouse remains a major barrier, particularly for small farmers. The crop also demands technical knowledge on temperature regulation, nutrient scheduling and pest monitoring for its success. Nevertheless, the opportunities far outweigh the constraints. Rising incomes, growing urbanisation and the spread of healthy diets ensure a steady demand for colourful, nutrient-rich vegetables. With government support, development of suitable hybrids and growing consumer awareness, coloured bell peppers are poised to become one of the flagship vegetables of protected cultivation in India.

Conclusion

From the green fields of Himachal Pradesh to the polyhouses of Maharashtra and Karnataka, coloured bell peppers represent both diversity on plate and prosperity in the field; they are symbols of the evolving Indian agricultural landscape. Nutrient-rich, visually appealing and economically rewarding, these bell peppers are enriching diets while improving farmer incomes. As protected cultivation spreads and awareness grows, it is likely that the coloured bell peppers will soon become as common in Indian kitchens as the traditional green ones, adding colour, health and profitability to the nation’s food basket.

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SCOPE OF VEGETABLE SEED PRODUCTION UNDER PROTECTED CULTIVATION

Abstract

India faces a persistent challenge in achieving consistent productivity and high-quality seed supply of vegetables. The shortage of superior quality hybrid and open-pollinated seeds is primarily due to the limitations of open field seed production, which is vulnerable to biotic stresses such as pests and diseases, and abiotic factors like temperature extremes and erratic rainfall. Protected cultivation offers a viable alternative for overcoming these challenges by enabling controlled environmental conditions that optimize plant growth, pollination, and seed development. Various structures including naturally ventilated greenhouses, insect-proof net houses, and low-cost polyhouses can be tailored for different climatic conditions and crop types to enhance seed productivity. Seed production practices such as the use of healthy seedlings, precise planting ratios of male and female parents, cluster pruning, regulated irrigation, and managed pollination significantly improve seed yield and quality. Protected environments also facilitate the maintenance of self-incompatible parental lines through controlled pollination and CO_2 treatment. The approach offers numerous benefits, including 2–4 times higher seed yield, improved seed viability and vigour, efficient use of water and nutrients, and reduced risk of viral infection. Overall, vegetable seed production under protected cultivation represents a sustainable, high-efficiency strategy that ensures the consistent supply of high-quality, virus-free hybrid seeds while mitigating environmental risks and optimizing resource use.

Keywords: Protected cultivation, seed quality, greenhouse, controlled environment and seed production.

Introduction

As India is the world's second-largest vegetable producer, following China, with an output of 196.27 million tonnes from 25.66 million hectares, it significantly surpasses advanced nations in average productivity. The deficiency of high-quality seeds of types and hybrids for extensive production is a significant factor leading to this imbalance. Another problem is the elevated expense of hybrid seeds for high-value vegetable crops, attributable to a poor seed production under open field circumstances.

Seed production in open field conditions is influenced by biotic pressures (pests and diseases) and abiotic stresses (environmental factors), which eventually impact growth, fruit and seed development, and yield (Monisha et al., 2024). Additional issues include the cultivation and sustenance of healthy, uniform seedlings, management of isolation distances, subpar seed output and quality, insufficient qualified personnel, and restricted access to places suitable for optimal seed production procedures of significant vegetable crops. Advancing vegetable seed growing under controlled environments may serve as a viable remedy to these issues.

Protected cultivation

It is a crop production method that involves the partial or complete regulation of a plant's microenvironment according to its requirements during its growth phase, aimed at optimising yield and resource conservation.

Selection criteria of structures suitable for seed production

The criteria for selecting protected structures for vegetable seed production depend on several key factors, including the climatic conditions of the chosen area, the specific crop, the type of plant seed, the period of production, and the desired quantity of seed output.

1. **Naturally ventilated greenhouses:** The edifices are suitable for the seed establishment of significant vegetable crops in both southern and northern Indian climates. Nonetheless, the length of the growing period and seed output are inferior than those in climate-controlled or semi-climate-controlled greenhouses.
2. **Insect-proof net houses:** These structures offer defence against viruses and various insects, such as fruit borers, throughout the humid and post-rainy seasons. In northern India, insect-proof net houses can be employed for the generation of parental line seeds and hybrid seeds during the summer and kharif seasons, in accordance with crop requirements and market demand. The seed yield will be inferior to that of all types of greenhouses; nevertheless, the cost of seed production is significantly cheaper than that of greenhouses.
3. **Low-cost polyhouse:** These structures are ideal for cultivating healthy, virus-free seedlings of open-pollinated varieties and parental lines for hybrid seed production in plug trays on elevated beds.

Importance of seed production practices of vegetables under protected structures

1. **Cultivation of vegetables in a healthy nursery for superior seed output**

Healthy, virus-free seedlings of open-pollinated types and robust seedlings of parental lines are essential for the generation of high-quality seeds in vegetable crops. Multi-celled plastic plug trays with a cell size of 1.5 inches, each possessing a volume of 18-20 cc, are utilised. Coco-peat, vermiculite, and perlite are utilised as soilless substrates in a volumetric ratio of 3:1:1. This promotes robust root development and prevents mechanical injury to the seedlings' roots during transplantation.

2. **Planting**

Vegetable crops must be seeded in rows to provide effective crop protection measures such as roguing practices and field inspections. Hybrid planting requires the male and female parent lines to be established in a specific ratio. The male to female plant ratio is 1:5 for tomato, cucumber, and summer squash; 1:4 for okra; 1:3 for muskmelon; and 1:6 for watermelon.

3. **Cluster pruning**

The quantity of fruits per cluster in vegetables that yield in clusters determines the quality and yield of both the fruit and seed. It also enhances the overall dimension of the fruit and the consistency of fruit ripening. Generally, retaining 4 to 5 superior fruits is essential for enhancing fruit quality and improving seed quality.

4. **Pollination management**

The lack of natural wind in covered structures necessitates the implementation of supplementary pollination strategies. Vegetables cultivated within covered buildings require daily pollination either human pollination, electronic pollinators, or bees. Bees in open environments exhibited reduced time spent on flowers compared to those in net house conditions. This may result from the abundance of blooms relative to the limited number of bees. The extended duration that bees spend in flowers in protected structures significantly enhances the assurance of pollination and seed set, resulting in superior quality and production of seeds.

5. **Irrigation**

Irrigation throughout important phases such as sowing, flowering, fruit set, seed filling, and seed maturity is essential and should be administered at an optimal pace. Withholding irrigation during harvest facilitates earlier and expedited ripening; water can also be employed to stagger and synchronise vegetable hybrid production of seeds. Excessive watering can encourage vegetative growth, lodging, and nutritional imbalance, whereas insufficient irrigation can postpone flowering, inhibit growth, diminish seed filling, and result in premature drying.

Maintenance and multiplication of self-incompatible lines for hybrid seed production

In cauliflower, there exists a challenge in sustaining and propagating possible self-incompatible lines for the development of F_1 hybrid seed. The temporary removal of self-incompatibility through the application of CO_2 gas has resolved this issue. The greenhouse is securely sealed for 2-6 hours post-pollination and is treated with 2-5% CO_2 gas, facilitating successful fertilisation by temporarily overcoming self-incompatibility, while bees are permitted to pollinate the crop during its flowering phase. Consequently, the self-pollinated seeds can be harvested to preserve the lines for future utilisation (Monisha et al., 2025).

Significant benefits of vegetable seed production in controlled environments

1. Enhanced seed output (often 2-4 times more) and superior seed quality in comparison to open field conditions (Kumari et al., 2025).
2. Isolation distance can be regulated in cross-pollinated plants.
3. Attaining synchronisation of flowering in parental lines and staggered planting.
4. The optimal plant population can be sustained while ensuring an adequate ratio of male and female progenitors to enhance hybrid seed output.
5. There is no necessity to emasculate female parents due to the absence of insect pollinators.
6. Seed production is feasible under poor environmental circumstances, which is not achievable in open field settings (Babanjeet et al., 2024).
7. The cultivation of virus-free seed crops is feasible, although it is exceedingly challenging under open field circumstances.
8. The duration of seed crops is longer under sheltered settings compared to open field seed crops.
9. Protected environments facilitate the production of organic seeds.
10. Efficient utilisation of water and nutrients is feasible for seed production in controlled environments.
11. Agri-entrepreneurs might engage in the production of high-quality vegetable seeds.
12. The cost of vegetable seed production could be diminished under controlled conditions.
13. Seed crops are not adversely affected by unseasonal precipitation during their maturation, in contrast to open field seed crops.
14. Seed viability and vigour may be enhanced through improved nutrition management in seed crops cultivated under controlled conditions.

Limitations

1. Insufficient understanding among farmers on the possibilities of protected vegetable seed production.
2. Insufficient comprehensive research initiative on the production of protected vegetable seeds.

3. It has been noted that farmers choose for protected agriculture solely to obtain subsidies and do not persist with crop or seed production.

Conclusion

Protected horticulture offers numerous advantages compared to open field seed production of vegetables. The advantage of vegetable hybrid seed production in controlled environments is its adaptability for implementation at both micro and macro levels, contingent upon specific needs, spatial constraints, and seed crop requirements. This method is exceptionally efficient, suitable for automation, conserves water, fertiliser, and land, and creates the necessary conditions to mitigate biotic and abiotic stress, hence improving both yield and seed quality. Protected cultivation provides an optimal environment for the production of healthy, virus-free, and genetically pure hybrid seeds, resulting in increased seed output per unit area.

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LEADERSHIP FOR THE AGRICULTURAL REVOLUTION v.4.0: EVERGREEN & EVERGROWING

Introduction

The history of the implementation of the 3rd Agricultural Revolution – the so-called Green Revolution - in India is a compelling narrative of a nation's journey from chronic food scarcity to self-sufficiency. In the mid-20th century, a rapidly growing population coupled with frequent droughts and an agrarian system based on traditional, low-yield farming practices created a perilous food crisis. The specter of famine, most notably the Bengal famine of 1943, loomed large, compelling policymakers and scientists to seek a radical solution. Further, the failure of southwest monsoon during the two consecutive years, 1965 and 1966, compelled India for large scale import of food grains. This urgent need for increased food production became the impetus for a monumental shift in agricultural policy, which came to be known as the “Green Revolution in India”. The movement, spearheaded in India by the agricultural scientist M.S. Swaminathan and C. Subramaniam, the food and agriculture minister, was fundamentally a package of modern farming technologies designed to dramatically boost crop yields, particularly for wheat and rice. Key to this transformation was the introduction of high-yielding variety (HYV) seeds, which were cross-bred to be more responsive to fertilizers and irrigation, alongside the widespread adoption of chemical fertilizers, pesticides, and modern machinery.

While the Green Revolution's primary objective was to avert a national food crisis, its consequences were far-reaching and multifaceted. On the one hand, its success was remarkable and immediate. India's food grain production soared, transforming the country from a net importer to a food-surplus nation and securing its food security. This newfound abundance led to greater national self-reliance and improved rural incomes in regions where the revolution was most successful, particularly in Punjab, Haryana, and Western Uttar Pradesh. The increased demand for labor in these areas also stimulated rural employment, and the surplus food production helped to curb inflation. However, the revolution was not without its substantial limitations and huge negative consequences.

The benefits of the Green Revolution were not evenly distributed, creating stark regional and social disparities. The technology package—which required significant capital for irrigation, fertilizers, and machinery—was largely accessible only to wealthy farmers in well-irrigated regions. This left small and marginal farmers, particularly in rain-fed areas, behind, leading to a widening gap between the rich and poor in rural India.

Furthermore, the intensive use of chemical inputs and groundwater has had severe environmental repercussions and irreparable loss to these natural resources. Decades of monoculture farming and the indiscriminate application of synthetic fertilizers and pesticides have led to soil degradation, reduced biodiversity, and the contamination of water bodies. The over-extraction of groundwater for irrigation has also caused a dramatic decline in water tables, posing a long-term threat to agricultural sustainability. These adverse effects highlight the critical need for a more sustainable and equitable approach to agriculture, a concept that led to the much hyped “Second Green Revolution” or "Evergreen Revolution" that prioritizes ecological preservation alongside food production. The Green Revolution, therefore, stands as a complex historical event, a necessary intervention that solved an immediate problem but also created a new set of challenges that continue to shape India's agricultural landscape. The craze for growing only the HYVs of wheat and rice by the farmers and absence of prudent advisory to conserve indigenous varieties side-by-side led to enormous genetic erosion of biodiversity.

The revolution's singular focus on the two staple food grains inadvertently created a significant disparity in the production of other essential agricultural commodities, particularly minor cereals, millets, pulses and oilseeds besides vegetables and fruits. These crops were largely left out of the technological and infrastructural advancements, leading to stagnant yields and a growing gap between domestic production and consumer demand. This neglect has resulted in India's persistent reliance on imports for these crucial dietary components, compromising the nation's nutritional security and economic stability. Therefore, the imperative for a "Green Revolution 2.0" has emerged, one that aims for a more comprehensive and inclusive agricultural transformation. This second wave of reform seeks to leverage new technologies and sustainable practices to boost the production of all agricultural commodities, thereby achieving true self-reliance and relieving the country's dependence on importing any agricultural produce. The 4th Agricultural Revolution (AR v4.0), projected in India by some people as “The Green Revolution 2.0” is not just about producing more food; it's about producing it sustainably, equitably, and resiliently. The leadership required for this paradigm shift must be able to innovate while preserving the environment, a concept that can be expressed by the equation:

AR v4.0 Leadership = Technological Expertise + Ecological Wisdom + Social Consciousness

Evergreen leadership can only be generated through a critical analysis of the present education system and the evolution of a new strategy. The current system, largely a product of the industrial revolution, often prioritizes rote memorization, standardized testing, and a one-size-fits-all approach. This model, while efficient for producing a workforce for a more mechanical age, stifles the very qualities essential for modern leadership: adaptability, creativity, critical thinking, and empathy. Leaders today operate in a complex, fast-paced world that requires them to not only solve problems but also to anticipate them and innovate effective and simple solutions. The traditional education system, by valuing conformity over curiosity, fails to cultivate these vital skills.

THE PERCEPTION PROBLEM

The perception problem in agricultural education is a significant barrier to attracting talented students. The core issue lies in the widespread belief that agriculture is a low-paying, low-prestige field with limited career advancement, causing many students, both urban and rural, to pursue more "lucrative" professions like medicine and engineering.

Urban vs. Rural Student Mindsets

The perception problem manifests differently between urban and rural students.

- **Urban students** often have a **disconnected, romanticized, or uninformed view of agriculture**. They may not see its modern, tech-driven aspects (e.g., Agrotech, data science, 'omics-driven genetics) and instead associate it with slow-paced, manual labor. This lack of a clear mindset and understanding of rural issues prevents them from recognizing the potential for impactful and innovative effort.

Rural students may view agriculture as the field they are trying to **escape**. They see the struggles of their communities firsthand—the financial instability, the hard work, and the limited opportunities—and aspire to careers that promise greater economic security and social mobility. They seek to move away from, rather than improve, the very systems they grew up with.

This dual challenge creates a cycle where the agricultural sector loses out on a crucial pool of talent.

UNPLANNED GROWTH OF AGRICULTURAL EDUCATION

Expansion of agricultural education without the right infrastructure and professional faculty creates significant challenges that undermine the very purpose of these institutions. The establishment of new agricultural universities and educational institutions often lacks essential resources, including **model classrooms, modern laboratory facilities, and dedicated research farms**. This absence of a proper learning environment leads to a failure in producing graduates who are well-equipped for the demands of modern agriculture.

A modern agricultural education requires a hands-on, practical approach that cannot be delivered in a theoretical vacuum. Without **model classrooms** that integrate smart technology and collaborative learning spaces, students are confined to outdated teaching methods. The lack of **modern laboratory facilities** prevents them from gaining practical experience with cutting-edge tools in biotechnology, nanotechnology, soil science, and food processing. Similarly, the absence of functional **research farms** means students can't engage in crucial fieldwork, such as crop trials, livestock management, and the application of precision agriculture techniques. This lack of a complete learning ecosystem leaves students with theoretical knowledge but no practical skills, making them uncompetitive in the job market.

Even with some infrastructure, the quality of education hinges on the faculty. A shortage of qualified professors who are actively involved in research and possess industry experience leads to several problems. The curriculum often becomes **stagnant and outdated**, as instructors cannot keep up with the rapid pace of technological advancements in agriculture. Moreover, the institution's ability to conduct meaningful research that addresses regional agricultural issues is severely limited. Without a **strong research faculty**, the university cannot generate new knowledge, develop innovative solutions, or attract funding. This ultimately results in poor student outcomes and a declining reputation for the institution.

This expansion-without-infrastructure model creates a vicious cycle. The poor quality of education and the lack of practical skills lead to a low reputation for agricultural degrees, which in turn discourages bright students from enrolling.

This reinforces the perception that the profession offers low salaries and slow growth, leading to a talent drain. Rural students, who have firsthand experience with agricultural challenges, are particularly motivated to seek education elsewhere. Urban students, already disconnected from the field, see little reason to enter it. Without a talented student body and a professional faculty, these institutions cannot produce the innovators and leaders needed to address critical issues like food security, climate change, and rural development. The result is a system that fails to serve either the students or the agricultural sector it was created to support.

OBSOLETE CURRICULUM

The primary curriculum for agricultural education has become obsolete, failing to keep pace with the rapid integration of technology into modern agriculture. Today's agriculture is a highly sophisticated, data-driven, and interdisciplinary field, a reality that the traditional education model, with its focus on basic crop and soil science, largely ignores. This disconnect creates a significant skills gap, producing graduates who are unprepared to work in a technology-driven industry, further fueling the perception problem and discouraging talented students. A traditional curriculum often emphasizes manual farming practices and basic agronomy, neglecting to incorporate the essential skills needed for modern farming. Students are not being taught how to:

- **Analyze Big Data:** Modern farms generate vast amounts of data from sensors, drones, and satellites. An obsolete curriculum does not prepare students to interpret this data for precision farming decisions regarding irrigation, fertilization, and pest control.
- **Insufficient Focus on Sustainability and Climate Change:** Traditional curriculums rarely address climate-smart agriculture, environmental stewardship, or sustainable resource management, which are increasingly critical under current global challenges.
- **Fragmented and Uncoordinated Programs:** There is limited integration across research, teaching, and extension functions, resulting in knowledge gaps and poor practical adoption of new innovations among farmers and students.
- **Operate and Maintain Modern Technology:** Today's agriculture relies on automation and robotics, from autonomous tractors to robotic harvesters. Students need to be trained in the operation and maintenance of these systems, as well as the underlying principles of AI and machine learning that power them.
- **Utilize Biotechnology and Genomics:** The future of food security is tied to advanced genetic modification, gene editing, and bioinformatics to create more resilient and nutritious crops. A traditional curriculum may not even touch upon these topics.
- **Manage Supply Chains with Blockchain:** The modern food system requires transparency and traceability. Without an understanding of technologies like blockchain, graduates cannot manage or innovate within complex global food supply chains.

Evolving the Curriculum for a Technology-Driven Future

To address this, Indian Agricultural Universities Association (IAUA) should oversee that agricultural education must undergo a fundamental transformation in consultation with the state chapters of the Indian National Farmers' Academy (infa.org.in) The new curriculum must be interdisciplinary and flexible, integrating technology into every aspect of learning. This includes:

- **Core Technology Modules:** All students should be required to take foundational courses in data science, GIS, AI, and robotics, specifically tailored to agricultural applications.
- **Hands-on Experiential Learning:** Learning must move beyond the classroom. Students should have access to research farms and labs equipped with the latest Agrotech tools. This includes hands-on experience with drones, sensors, and automated irrigation systems.
- **Emphasis on Problem-Solving and Innovation:** The curriculum should be project-based, challenging students to use technology to solve real-world agricultural problems, from increasing crop yields in a specific region to developing sustainable farming practices.

By modernizing the curriculum, agricultural education can shift from teaching "how to farm" to teaching "how to innovate and lead in the agricultural sector." This change is crucial to attract a new generation of students who see agriculture not as a traditional profession, but as a dynamic and vital field at the intersection of technology, sustainability, and global food security.

POOR INDUSTRY LINKAGES

Poor industry linkages with agricultural education create a significant gap between the skills taught in academia and the skills demanded by the modern agricultural sector. This disconnection leads to graduates who lack practical experience and industry-specific knowledge, making them less employable and perpetuating the perception of agriculture as a low-tech field. The lack of strong connections between agricultural universities and agribusinesses has several negative consequences:

- **Outdated Academic Programs**: Without regular input from industry, academic curricula can become stagnant, focusing on traditional, obsolete farming methods while ignoring advancements in **Agrotech**, **data analytics**, and **sustainable practices**. This means students are learning about yesterday's agriculture in a field that's moving at a rapid pace.
- **Lack of Practical Skills**: Industry jobs require hands-on experience with modern equipment, software, and real-world problem-solving. Without structured internship programs, joint research projects, and guest lectures from industry professionals, graduates are left with theoretical knowledge but no practical skills.
- **Limited Research Relevance**: Academic research can become detached from the immediate needs of the industry. Without collaboration, universities may focus on theoretical or niche topics that have little commercial application, failing to address the pressing challenges faced by farmers and agribusinesses, such as optimizing yields or developing new crop varieties.
- **Poor Job Placement**: The disconnect makes it difficult for universities to place their graduates in high-paying, high-impact jobs. Employers, in turn, may be hesitant to hire agriculture graduates, preferring to train individuals from other fields who have more relevant technical skills. To bridge this gap, a collaborative, proactive approach is necessary, involving both academia and industry.
- **Joint Curriculum Development**: State Agricultural Universities (SAUs) in consultation with State Chapters of the Indian national Farmers' Academy should form advisory boards with industry leaders to regularly review and update the curriculum. This ensures that course content is aligned with industry needs and includes emerging technologies and business practices.

Mandatory Internships and Co-op Programs: All agricultural education programs should require students to complete mandatory internships or co-op placements. This provides students with hands-on experience, allows them to apply their knowledge, and gives them valuable networking opportunities.

- **Collaborative Research and Development**: Universities and companies should partner on **joint research projects** that address real-world industry problems. This can lead to the development of new technologies, products, or practices while also providing students and faculty with research funding and practical experience.

Faculty and Student Exchanges: Encourage faculty to spend time working in industry and invite industry professionals to teach or mentor students. This two-way exchange of knowledge keeps faculty informed of industry trends and provides students with practical insights.

By strengthening these linkages, agricultural education can move from being a source of generic knowledge to a dynamic pipeline of highly skilled, adaptable, and innovative professionals ready to lead the future of the agricultural sector.

GOVERNMENTS‘ APATHY AND POLICY GAPS

State Governments’ apathy and significant policy gaps are major contributors to the poor state of agricultural education. A lack of strategic vision and sustained investment has left the system unable to meet the needs of a modern, technology-driven agricultural sector. This neglect manifests in several key areas, from funding to policy implementation. Despite agriculture's critical role, government funding for agricultural education and research is often inadequate. This translates directly to a shortage of resources, preventing institutions from acquiring **modern laboratory facilities**, **model classrooms**, and developing functional **research farms**. Instead of being a priority for investment, agricultural education is frequently left to function on outdated budgets, which perpetuates the cycle of poor infrastructure and attracts neither a professional faculty nor ambitious students. This lack of financial commitment reflects a broader policy gap where the government's focus is on short-term food production targets rather than on long-term capacity building through education.

While some policies may exist on paper to support agricultural education, their implementation is often weak or fragmented. The state governments’ failure to effectively bridge the gap between academic institutions and the agricultural industry is a prime example of a policy gap. There is a lack of incentives for industries to collaborate with universities on curriculum development, research, and internship programs. This means that even if a policy exists, without a clear implementation strategy, it fails to produce tangible results. Furthermore, the lack of a cohesive national policy that recognizes and integrates agricultural education into the broader national development agenda creates a siloed approach, where institutions work in isolation without a unified vision. The IAUA may play a central role for this mission.

The direct result of governments’ apathy and policy gaps is a system that fails to produce **innovative and skilled graduates**. The lack of strategic investment means agricultural graduates are not trained in the latest technologies, making them less competitive in the job market. This feeds into the negative perception of agricultural careers, which further discourages students from enrolling. Ultimately, the governments’ failure to prioritize agricultural education is a major barrier to the growth and modernization of the agricultural sector, impacting not only food security but also rural development and the nation's economic potential.

FACULTY SHORTAGE AND SKILL GAPS

Addressing the **faculty shortage and skill gaps** requires a more holistic approach. A great agricultural educator needs a blend of communication skills, academic excellence, and the qualities of a mentor to truly impact students and the future of the sector. The current system often over-prioritizes academic degrees, like a Ph.D., as the sole criterion for faculty recruitment. While academic qualifications are important, this narrow focus leads to a number of problems:

- **Poor Communication Skills:** Many highly qualified academics may lack the ability to effectively communicate complex concepts to students. This results in a disconnect, where knowledge is not transferred efficiently, and students struggle to grasp the material.
- **Lack of Practical Knowledge:** Faculty recruited solely for their research or academic background may have limited or no practical experience in modern agribusiness. They can teach theory but may not be able to provide students with a real-world perspective on challenges and opportunities in the field. This perpetuates a curriculum that is out of sync with industry demands.
- **Absence of Mentorship:** A good educator does more than just lecture. They guide, inspire, and mentor students. Without the qualities of a mentor, faculty fail to foster critical thinking, problem-solving, and professional development in their students. This stunts the growth of future leaders who need more than just textbook knowledge.

To fix this, agricultural education institutions must adopt a new recruitment strategy that looks for a combination of skills.

- **Lead-from-the-front Administration:** SAUs should recruit Vice-Chancellors with proven record of educational excellence and academic experience.
- **Communication Skills:** During the hiring process, faculty members should be evaluated on their ability to present complex topics clearly and engage an audience. This can be done through teaching demonstrations or presentations on their research.
- **Farm/Industry Experience:** Institutions should prioritize candidates who have practical experience in the agricultural sector. This could include working in agribusiness, managing a farm, or conducting applied research with industry partners. This experience ensures that the curriculum is relevant and up-to-date. IAUA should recommend mandatory internships of substantial period for agricultural degrees.
- **Mentoring Qualities:** Recruiters should look for candidates who demonstrate an interest in student success beyond the classroom. This could be seen in a history of supervising student projects, advising student clubs, or participating in outreach programs. These qualities are essential for building a supportive learning environment.

By focusing on these three key areas, institutions can build a faculty that not only possesses deep academic knowledge but also the communication and mentoring skills necessary to train the next generation of innovative and effective agricultural leaders.

LOW OR IRRELEVANT RESEARCH

The issue of low or irrelevant research output in agricultural education is a direct result of the academic reward system. When faculty career advancement, promotions, and tenure are tied almost exclusively to publications in prestigious, high-impact journals, it incentivizes a kind of research that often has little to no relevance to real-world agricultural problems. This system creates a significant disconnect. High-impact journals often favor highly theoretical, niche, or esoteric research that is scientifically complex but has limited practical application. Faculty are pressured to pursue topics that satisfy academic reviewers rather than addressing the pressing needs of farmers, agribusinesses, or rural communities. For example, a professor might publish a complex genetic study on a rare plant species, which may earn them a top-tier publication, while a more practical study on how to improve crop yields for a common local crop goes unwritten. This focus on academic prestige over practical relevance has several consequences:

- **Stagnant Local Innovation:** Research that could solve local problems—like pest outbreaks, soil degradation, or water management issues—is not prioritized, leading to a lack of innovation at the regional level.
- **Loss of Public Trust:** When the public, especially farmers and industry leaders, sees academic research as irrelevant and detached, it erodes trust in agricultural institutions and their ability to provide solutions.
- **Lack of Practical Student Training:** Students are often involved in this type of theoretical research, which doesn't prepare them for the applied, problem-solving demands of the modern agricultural industry. They may learn how to conduct a complex genetic experiment but not how to use data to optimize fertilizer application on a farm.

To fix this, agricultural education institutions need to realign their research incentives. Faculty should be rewarded not just for the prestige of their publications but also for the **impact and relevance of their research**. This can be achieved by:

- **Expanding Evaluation Criteria:** Career advancement should consider a wider range of metrics, including patents, successful technology transfers, extension work, community engagement, and publications in journals or reports that are widely read by industry professionals and farmers.
- **Promoting Interdisciplinary and Collaborative Research:** Institutions should encourage and reward faculty who collaborate with agribusinesses, government agencies, and farmers on problem-oriented research. This ensures that the research addresses real-world needs.
- **Establishing an Applied Research Culture:** The culture of the institution itself should value and promote applied research as highly as theoretical work. This can be done through dedicated funding for applied projects and by showcasing the real-world impact of faculty research.

By making these changes, agricultural education can shift from a system that rewards academic prestige to one that celebrates and incentivizes research that truly serves the agricultural sector and contributes to solving real-world problems.

LANGUAGE AND ACCESSIBILITY BARRIERS:

Language and accessibility barriers in agricultural education create significant challenges, hindering the dissemination of knowledge and excluding a large portion of the rural population. The primary issue is the reliance on English as the medium of instruction and research, which alienates students and farmers who primarily speak regional or local languages.

- **English as a Barrier:** While English is a global language of science and business, its dominance in agricultural curricula and research publications creates a major hurdle. Many students from rural backgrounds, who often attend government schools where regional languages are the primary medium, struggle to grasp complex scientific concepts when taught in English. This not only impacts their academic performance but also makes them less confident in their abilities. SAUs may introduce education through the language of the state.
- **Exclusion of Farmers:** The lack of accessible content in local languages directly impacts the ability of extension services to effectively communicate new agricultural technologies and practices to farmers. Research findings published in English-only journals remain inaccessible to the very people who could benefit most from them. This knowledge gap contributes to lower productivity and perpetuates traditional, less efficient farming methods.
- **Urban-Rural Divide:** The language barrier reinforces the urban-rural divide. Urban students, who are often more proficient in English, are at an advantage, while rural students, who have firsthand experience with agricultural challenges, are at a disadvantage. This leads to a brain drain, where talented rural students are unable to pursue higher education in agriculture, and those who do, often struggle to succeed.

To address these challenges, a multi-pronged strategy is required to make agricultural education more inclusive and accessible.

- **Multilingual Content:** Educational institutions and government agencies must develop and disseminate research and educational materials in **multiple regional languages**. This includes translating textbooks, creating video tutorials, and publishing research summaries in local dialects.
- **Bilingual Instruction:** Implement bilingual teaching methods where complex scientific terms are introduced in English but explained using local language analogies and examples. This can help students bridge the language gap gradually.
- **Leverage Technology:** Utilize technology to create a network of agricultural information that is accessible in various languages. Apps, websites, and radio programs can be developed to provide real-time information on crop diseases, weather forecasts, and market prices in local languages.
- **Empower Local Experts:** Train and empower local community leaders and agricultural extension workers to serve as a bridge between researchers and farmers. These individuals, fluent in local languages, can effectively translate and demonstrate new practices.

By breaking down these language and accessibility barriers, agricultural education can become a powerful tool for empowering rural communities, fostering innovation, and ensuring that the knowledge and research generated actually reach those who need it most.

LACK OF ENTREPRENEURSHIP TRAINING

The lack of entrepreneurship training in agricultural education is a significant missed opportunity. It prevents agricultural graduates from seeing themselves not just as job seekers, but as job creators. Instead of equipping them to be innovative business owners, the current curriculum often prepares them for traditional, salaried roles, leaving a void in crucial areas like input supplies, food processing, and rural services. The traditional agricultural education system often overlooks the importance of business acumen. Graduates are taught the science of agriculture but lack the skills to monetize that knowledge. This leads to a number of issues:

- **Limited Self-Employment:** Graduates are often unprepared to launch their own ventures, such as providing **custom hire services** (e.g., modern farm equipment rental), setting up **input supply businesses** (e.g., selling seeds or fertilizers), or becoming an **agricultural practitioner** offering expert advice to farmers.
- **Brain Drain:** Without viable self-employment opportunities, talented graduates from rural areas are compelled to move to urban centers in search of jobs, contributing to rural decay and a loss of local expertise.
- **Missed Opportunities in Food Processing:** The curriculum often lacks the business training needed to create small-scale **food processing industries** that could add value to local produce, reduce waste, and generate income within the community.
- **Failure to Capitalize on Rural Administration:** Graduates could play a key role in **rural administration** by using their expertise to advise local governments on agricultural policy and development projects, but they often lack the entrepreneurial drive to create these roles for themselves.

To address this, agricultural education must shift its focus to include a strong emphasis on entrepreneurship. This new approach should include:

- **Practical Business Skills:** Courses should be introduced on market analysis, business plan development, financial management, and marketing specifically for the agricultural sector.
- **Mentorship and Incubation Centers:** Universities should partner with agribusinesses and successful entrepreneurs to create mentorship programs and business incubators. These centers would provide graduates with a supportive environment to develop and launch their ventures.
- **Project-Based Learning:** Students should be challenged to create and present business plans based on real-world opportunities, like setting up a local food processing unit or a farm-to-table delivery service. This hands-on experience is crucial for building confidence and practical skills.

By integrating this entrepreneurial training, agricultural education can transform its role from simply producing employees to empowering a new generation of innovative business leaders who can revitalize rural economies and create a more sustainable and prosperous agricultural sector.

The Consequences of Non-Professional Leadership

Manning agricultural leadership roles with non-experts is like trying to fly a plane without a trained pilot: it is directionless, dangerous, and eventually disastrous. This is because these positions require a deep understanding of complex systems, from soil science and genetics to global supply chains and climate trends. When these roles are filled by individuals without the necessary expertise, it leads to:

- **Ineffective Decision-Making:** Non-professionals lack the foundational knowledge to make sound decisions on critical issues like pest management, resource allocation, and market strategy. This can lead to significant economic losses for farmers and the country.

- **Stagnant Innovation:** Without leaders who understand the latest advancements in **Agrotech**, biotechnology, and sustainable practices, the sector fails to innovate. Research becomes irrelevant, and the adoption of new technologies slows down, leaving the country's agricultural output behind global competitors.
- **Erosion of Trust:** When professionals see that leadership roles are not based on merit or expertise, it demotivates them and can lead to a "brain drain," where the most talented individuals leave the sector. This also erodes public and industry trust in agricultural institutions.

A Call for Strategic Professionalism

To ensure the future of agriculture, leadership positions must be filled by qualified professionals who possess a blend of academic expertise and practical experience. This requires a strategic shift in government policy and institutional hiring practices. By prioritizing merit and professional qualifications, we can ensure that the agricultural sector is guided by capable hands, capable of steering it toward a prosperous, sustainable, and innovative future.

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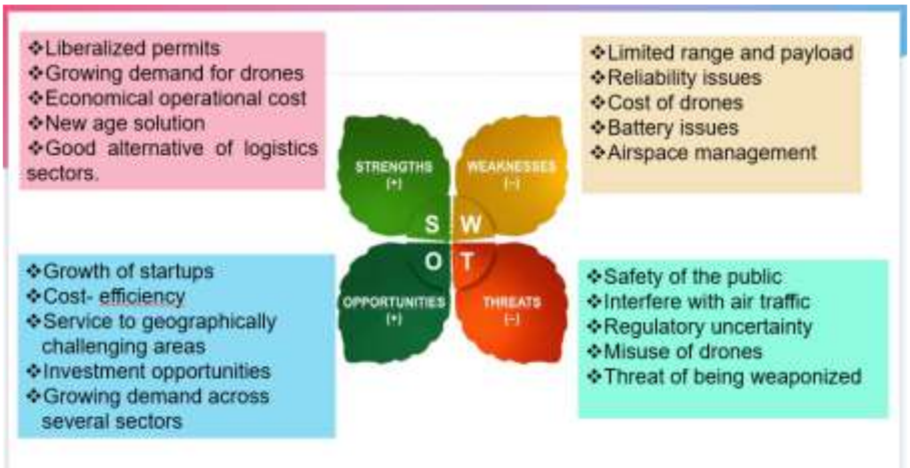
PRECISION FROM THE SKY: DRONE TECHNOLOGY RESHAPING INDIAN AGRICULTURE

1. Introduction: From gadgets to farm tools

In recent years, drones, formally known as **"Unmanned Aerial Vehicles (UAVs)"**, have transformed from military machines to essential agricultural tools. Fitted with high-resolution cameras, sensors, GPS and spraying systems, drones are helping farmers monitor crops, apply fertilizers and pesticides with precision and save both time and money (Rejeb *et al.*, 2022). The global agricultural drone market was valued at around USD 6 billion in 2024 and is projected to reach over USD 20 billion by 2032 (Fortune Business Insights, 2024). In India, the agricultural drone market is expanding rapidly, expected to grow from about USD 145 million in 2024 to over USD 630 million by 2030 (Grand View Research, 2024). India is catching up through initiatives such as the Drone Shakti Scheme, the Kisan Drone Yojana (providing subsidies for agricultural spraying and mapping) and the Production Linked Incentive (PLI) Scheme for domestic drone manufacturing (IBEF, 2024).

2. Historical development of drone applications in agriculture

The journey of drones into agriculture began decades ago. While the earliest unmanned aerial systems date back to 1849, when the Austrian military used explosive balloons, agriculture saw its first breakthrough in 1983, when Yamaha company from Japan developed a remote-controlled aerial spraying system for rice fields (Pradhan *et al.*, 2025).



SWOT analysis of drone technology

In the 1970s, Abraham E. Karem, often called the **"Father of UAV Technology"**, pioneered key designs that led to the development of the modern predator drone, which later influenced civilian and agricultural drone designs (Rejeb *et al.*, 2022). In India, agricultural drone adoption accelerated after 2021, when the Government of India liberalized drone rules and permitted institutions such as, ICAR and ICRISAT to conduct field trials for crop research and spraying demonstrations (Beriya, 2022; Press Information Bureau, 2022).

3. Functional roles of agricultural drones

Modern agricultural drones are versatile, performing several critical tasks. They can conduct soil and field analysis to assess moisture, nutrient status and topography, monitor crop health for early detection of pests, diseases and water stress, plant seeds by dropping nutrient-filled pods in targeted locations and **spray fertilizers or pesticides quickly and evenly**, thereby reducing the chemical use and farmer exposure (Borah *et al*, 2025a). Emerging applications include irrigation scheduling through thermal mapping, livestock monitoring *via* infrared sensors and pilot projects using drones to establish **"geofences"** for protecting fields from animal intrusion (Komatineni *et al.*, 2024; IBEF, 2024).

4. Scientific evidence from field trials

Field research in India is proving their value. A study conducted at TNAU found that, spraying of 2 per cent TNAU Pulse Wonder nutrient mix on green gram using drones resulted in taller plants, more pods and a grain yield of 747 kg/ha, significantly higher than manual spraying, while using far less water (Dayana *et al.*, 2021; TNAU Annual Report, 2023). In Telangana, paddy seed-production trials showed that drones completed spraying in a fraction of the manual time, reduced labour needs by nearly 70 per cent and improved coverage uniformity. Similarly, a University of Agricultural Sciences, GKVK, Bengaluru pilot project reported that, drone spraying in ragi and tur dal reduced water usage by nearly 90 per cent and increased yields by 5 to 10 per cent (Times of India, 2025a).

5. Economic benefits and farmer adoption

The economic benefits are equally encouraging. Field demonstrations coordinated by Krishi Vigyan Kendras (KVKs) in Tamil Nadu and Karnataka have shown cost savings of 15 to 20 per cent compared to conventional spraying, primarily due to reduced labour requirement and chemical wastage (Yazhini *et al.*, 2024). Moreover, demonstrations by KVKs have significantly increased farmer knowledge about drone applications, especially in pest monitoring, sowing and irrigation scheduling.

6. Policy support and government initiatives

India's policy framework is actively promoting drone adoption. Subsidy schemes under the "**Sub-Mission on Agricultural Mechanization"** offer up to 100 per cent funding for research institutions and 75 per cent for farmer groups. States like Bihar and Uttar Pradesh are launching training and subsidy drives, while women **"Drone Didis"** are being celebrated for leading this technological shift in rural areas

(Economic Times, 2025; Times of India, 2025b). These measures aim to make drones accessible even to smallholder farmers who cannot afford to buy them outright.

7. Challenges and limitations

Despite their promise, challenges remain. High initial cost, limited availability of trained operators, dependence on reliable GPS and weather conditions and difficulties in interpreting drone-generated data all slow adoption (Puppala *et al.*, 2023; IBEF, 2024). For small farmers, ownership is often unaffordable, but custom hiring centres (CHCs), farmer producer organizations (FPOs) and government backed service providers are helping bridge this gap.

8. Future prospects

As technology advances, drones will likely integrate artificial intelligence for autonomous navigation and decision-making, extend battery life and become cheaper to operate. Research indicates that improved payload capacity, better flight stability and AI-based crop analytics will further enhance their efficiency (Borah *et al.*, 2025b).

If current trends persist, drones may soon become as common on Indian farms as tractors, symbolizing a major leap toward smart, precise and sustainable agriculture.

9. Conclusion

The integration of drone technology in Indian agriculture represents a transformative step toward precision, sustainability and efficiency in farm management. Drones enable real-time crop monitoring, targeted pesticide spraying and resource optimization, thereby reducing input costs and environmental impact. Their use supports data-driven decision-making, enhancing productivity and resilience to climatic stress. With sustained government support and ongoing research advancements, drone-enabled smart farming is set to transform the future landscape of Indian agriculture.

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THE HIDDEN WORLD OF LICHENS: PARTNERS IN ECOLOGY AND AGRICULTURE

Abstract

Lichens cover about 7% of Earth's surface vegetation, and there are at least 18,000 lichen species around the world. Lichens thrive in various climatic conditions and are abundantly seen in the Tundra regions. They are of different types and are available in bright, vibrant colours. Their ability to fix nitrogen makes them valuable bioindicators of environmental quality. This article reviews lichen, its types and their importance in the agricultural sector.

Introduction

Lichens are a symbiotic relationship between a fungus and an alga. Their relationship is considered to be mutualism. Lichens can be found in soil, water, rocks, and trees, and are an excellent indicator of air quality. They can also fix nitrogen from the atmosphere, making it available to the plants. They can also retain moisture and influence the microclimate around them. Thus, their importance can't be ignored. Moreover, research is ongoing on lichens for the production of bioactive compounds, such as antioxidants and compounds for therapeutic purposes. Some lichens, such as Ramalina lichen, are used to make perfumes, and others, like stone mushrooms, are used as food, and *Xanthoria parietina* is used to treat menstrual complaints and jaundice in several parts of the world.

What are Lichens?

The dominant partner of lichen is the fungus, which gives the lichen the majority of its characteristics. The alga can be either a green alga or a blue-green alga, otherwise known as cyanobacteria. Their chloroplasts are present in the algae on the lichen's upper surface, and they lack roots, stalks, and leaves. The multicellular, macroscopic lichen thallus gets its moisture from its surroundings. While some of them inhabit freshwater or marine habitats, the majority are terrestrial. Although they can grow on a variety of surfaces, lichens are most frequently found on exposed rocks, tree bark, or compacted soil. The ability of lichens to thrive in hostile conditions where algae would typically perish is another significant role they play. As long as there are occasional rain showers or flooding to let them replenish and store food for the next drought spell, these often water-dependent species can survive in arid, sunny areas because the fungus can shield its algae.

Because lichens allow algae to thrive in a wide range of climates, they also give us a way to employ photosynthesis to turn atmospheric carbon dioxide into oxygen, which is essential for human survival. Reproduction of lichens is different from plants. As the dominant partner is a fungus, it produces spores and fruiting bodies. These spores produce another fungus, but its algae cannot reproduce. Hence, the fungus has to find a new algal partner.

Types of lichens

Crustose-They form crust on the surface of trees or bark and cannot be removed without being destroyed, as it sticks tightly to the surface. They come in vibrant colours. (Graphis, Lecanora)

Foliose- Their body is flattened and leaf-like. There are two distinguishable sides, the top side and the bottom side. They play a key role in soil formation and nutrient cycling. (Parmelia)

Fructiose - Shrubby, bushy or hair-like. They can be seen upright or hanging. Often used as bioindicators. (Cladonia, Usnea)

Importance in agriculture

Lichens' capacity to absorb everything in their atmosphere, particularly contaminants, is one way they directly support agriculture. The lichen thallus absorbs any contaminants in the atmosphere, including carbon, sulphur, and heavy metals. These toxins can be extracted, and scientists can figure out how much of them exists in our atmosphere. As a result, they assist farmers in tracking pollution levels and act as bio-indicators of air quality. Additionally, they can fix atmospheric nitrogen and make it available to the soil and nearby plants. They also add organic matter to the soil once they die and aid in the development of the soil. They are also the first organisms that colonise barren lands and start the process of breaking down rocks, which leads to soil formation. Studies show that lichens contribute to high yields due to the extracts taken from them. These extracts, which are toxins, affect insects and can be used in the production of biological insecticides. The effects of the methanol extract of L. pulmonaria on *Drosophila melanogaster_ Meigen* (vinegar fly) were investigated (Uysal et al., 2009). They found it was very effective on their lifespan compared to the chloroform and water extracts of the same. Recently, different lichen extracts against storage pests have also gained popularity. Larvae of several lepidopteran species also feed exclusively on lichens, as well as the reindeer in the Arctic regions.

Conclusion

In conclusion, lichens are fascinating organisms that are very relevant to our environment. They are vibrant and very aesthetically pleasing. Each lichen has its own beauty and style. Several animals depend on lichens, such as the Northern flying squirrel, which uses them for nesting, and some adapt to look like lichens, which are a huge part of their habitat. They are not only a pollution indicator but also have significance in human health as well as in agriculture. Thus, more research on lichens can bring a big impact on these areas. This helps us to understand that the role of lichens is very important in ecology as well as in agriculture.

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CRISPR : The Future of Farming, Food, and Livestock Production

Abstract:

CRISPR, Clustered Regularly Interspaced Short Palindromic Repeats, is a powerful gene-editing technology used by the research scientist to improve the genotype of crops and livestock by targeted transgenic or non-transgenic approaches. It plays an important role in the improvement of crop productivity and livestock management and production, as it helps in the development of disease-resistant organisms. In Agriculture, it can be applied to develop climate-resilience and biofortified crops; while in the livestock sector, it can be applied to develop disease-resistant, high-yielding crops that ensure animal health and welfare. Overall, CRISPR is a revolutionary step to achieve food security and sustainability. This article reviews its applications, benefits, challenges, and concerns in the Agriculture and livestock sectors.

Introduction :

The current global population has surpassed 8.2 billion, and feeding this population is a challenging task. It is very important to reduce the impact of yield-reducing parameters – climate change, pest-disease outbreak, etc, on Agriculture. Use of the traditional breeding methods provides a slow and imprecise result. Scientists have discovered some tools to increase agricultural and livestock productivity in order to achieve food security; CRISPR is one among them. It is the technique used by the research scientist to modify the genotype of a living organism with useful traits. They can be used precisely to alter the genetic material with or without the addition of a foreign genome.

What is CRISPR-Cas9?

CRISPR is a technology that allows scientists to precisely modify genes by adding, deleting, or altering specific sections of DNA. It is recognized as the simplest, versatile, and accurate tool of genetic engineering. This technique is based on the natural bacterial defense mechanism against the viral genomes.

How does it work?

The system consists of two key molecules :

1. Cas9 – CRISPR-associated protein 9
2. gRNA – Guide RNA

Here, the gRNA acts as a GPS, as it finds and binds to a specific sequence of DNA. The Cas9 enzyme acts as a molecular scissor that makes cuts at targeted sites.

Once the gRNA finds the correct DNA sequence, the Cas9 enzyme follows and cuts both strands of the DNA at that particular point.

Cell repair occurs by Non-Homologous End Joining (NHEJ) or by Homology-Directed Repair (HDR), and desired modifications can be made.

Delivery of CRISPR in plants:

1. Agrobacteria delivery – Agrobacterium tumefaciens is used to transfer the Cas9 DNA into the plant genome. The Cas9 gene is inserted into the Ti plasmid vector. Later, when the plant gets infected by the bacteria, the Cas9 gene will be integrated into the host cell.
2. Protoplast delivery – Using PEG-mediated transfection, Cas9 components can be introduced directly into the cytoplasm of the host, with the help of isolated protoplasts.
3. Biolistic delivery/gene gun – Cas9 materials are coated on tiny gold or tungsten particles, and are shot into the host cell.
4. Viral vector delivery – Uses plant viruses as carriers of the Cas9 gene.

Delivery of CRISPR in livestock:

1. Microinjection – In this, the Cas9 gene is directly injected into the cytoplasm or pronucleus of a fertilized embryo with the help of micromanipulators.
2. Electroporation – Charged CRISPR molecules are created with the help of short electrical pulses to transfer them into the host cell.
3. Viral vectors – Modified and replication-deficient viruses are used in this method.
4. Liposomes – Here, CRISPR components are encapsulated with the help of lipid nanoparticles and are released into the targeted cytoplasm.

Applications in Agriculture :

- Pest and disease resistance – Used in the development of disease-pest-resistant varieties. For example, bacterial blight-resistant rice and powdery mildew-resistant wheat varieties.
- Nutritional enhancement – Used in the development of biofortified crop varieties with higher micro and macro nutrients.
- Improved shelf life – CRISPR was applied to develop mushroom and tomato varieties to improve the shelf life by reducing their browning and spoilage.
- Commercial properties - Decaffeinating coffee, creating seedless fruit, etc…
- Sustainable Agriculture – Reduced the bad impact on the environment as it reduces the use of chemicals.
- Abiotic stress-tolerant variety development.

Applications in the Livestock sector :

- Disease resistance –Used to develop cattle resistant to tuberculosis and other viral infections.
- Productivity enhancement – Can be used to control the milk yield and muscle growth.
- Promotes animal welfare.
- Development of climate-friendly animals.

Advantages in the Agriculture and livestock sectors :

- Highly precise and efficient
- Environmentally sound
- Healthier and climate-resilient crops and animals
- High productivity

- Stress-tolerant varieties
- Pest-disease resistance

Challenges :

- Delivery difficulties
- Ethical and animal welfare concerns
- High cost of production and technical expertise
- Off-target effects
- Industrial properties and copyright issues

Future prospect : In the upcoming decades, CRISPR has the potential to become the key to food security and sustainability through proper research and studies. Focused research is going on to study more capabilities of CRISPR in the development of desired traits in crops and livestock, promising high productivity and profitability without harming the environment.

Conclusion :

CRISPR is acting as a revolutionary tool in genetic engineering for the development of desired crops and animals that will transform the Agriculture and Livestock sectors, as it is based on targeted modification of the genome. It supports the vision of sustainable Agriculture as it helps in the development of stress-resistant, pest-disease-resistant, climate-resilient crops and animals that are environmentally safe by minimizing the use of harmful chemicals.

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SOIL SAMPLING TOOLS AND TECHNIQUES

Introduction

Soil sampling is a scientific method used to collect soil from a field or land at different locations and depths to analyze soil physical, chemical, and biological properties. It is an essential step in understanding the condition and fertility of the soil, which helps in making informed decisions about crop production, fertilization, irrigation, and soil management. The purpose of soil sampling is to gather representative samples that reflect the overall health and nutrient status of the soil. These samples are then tested in laboratories to measure pH, nutrient levels (such as nitrogen, phosphorus and potassium), organic matter, salinity, and other factors affecting crop growth.

- Accurate soil sampling helps farmers and agronomists.
- Identify nutrient deficiencies or toxicity.
- Improve fertilizer use efficiency.
- Minimized costs by applying the right quantity of inputs.
- Enhance sustainable crop yield and soil health.
- Prevent environmental pollution from overuse of chemicals.

Soil sampling is usually done before sowing a crop or periodically during crop growth to monitor changes in soil health. It forms the foundation for soil testing and plays a vital role in sustainable and precision agriculture. Proper sampling techniques ensure that the analysis represents the field's condition rather than localized spots, making the results more useful for agricultural planning.

Importance of Soil Sampling

Soil sampling plays a crucial role in modern agriculture and soil management. It helps farmers, researchers, and policymakers make informed decisions by providing accurate information about the condition of the soil. Below are the key reasons why soil sampling is important:

Determining Soil Fertility

Soil sampling helps to understand the nutrient status of the soil, such as nitrogen (N), phosphorus (P), potassium (K), organic matter, pH level, and other essential elements. This information is vital for applying fertilizers in the right amount, ensuring that plants get the nutrients they need without wastage or deficiency.

Efficient Use of Fertilizers

By knowing which nutrients are lacking or abundant, farmers can apply fertilizers more precisely. This leads to:

Reduced cost of inputs

Better crop yield

Prevention of nutrient imbalance

Less environmental pollution due to over-fertilization

Improving Crop Yield and Quality

Healthy soil with balanced nutrients contributes to better plant growth, improved resistance to pests and diseases, and higher yields. Soil sampling helps in providing appropriate recommendations that enhance both the quantity and quality of crops.

Monitoring Soil Health Over Time

Regular soil sampling allows farmers to track changes in soil properties over different seasons or years. This helps in:

✓ Early detection of nutrient depletion or toxicity

✓ Planning crop rotation and organic matter management

✓ Restoring soil health through corrective measures

Preventing Soil Degradation

Soil sampling helps identify issues such as soil acidity, salinity, compaction, or erosion. Early detection allows farmers to take preventive steps like applying lime to correct acidity, improving drainage, or adding organic matter to rebuild soil structure.

Promoting Sustainable Agriculture

Accurate soil testing and sampling lead to balanced nutrient management, water conservation, and reduced dependence on chemical fertilizers. This promotes eco-friendly farming practices that protect the environment and conserve natural resources.

Cost-Effective Farming

Soil sampling prevents unnecessary expenses on fertilizers and amendments. Farmers can apply nutrients only where needed and in appropriate amounts, optimizing resource use and reducing waste.

Environmental Protection

Excessive use of fertilizers or chemicals can lead to groundwater contamination, air pollution, and soil degradation. Soil sampling helps in applying the right amount of inputs, reducing runoff, and protecting the surrounding ecosystem.

Scientific Decision Making

Soil sampling provides reliable data that can guide agricultural decisions rather than relying on guesswork. It helps in planning cropping patterns, irrigation schedules, and input management based on actual soil conditions. Soil sampling is an essential tool for maintaining soil health, improving crop productivity, reducing costs, and protecting the environment. It ensures that farming practices are efficient, sustainable, and based on scientific evidence. Regular sampling and analysis empower farmers to take proactive measures, resulting in healthier soils, better crops, and long-term agricultural success.

Tools and Techniques

Soil sampling is a critical step for assessing soil health, fertility, and contamination levels. Accurate sampling ensures that laboratory analyses are representative of the field conditions. Below are commonly used tools and techniques in soil sampling:

Soil Sampling Tools

Soil Auger: Used to collect soil from different depths.

Types of Soil Sampling Auger

1. Hand auger: For small-scale sampling.
2. Power auger: For deeper or larger-scale sampling.

3. Soil Core Sampler: Cylindrical device that extracts intact soil cores. Good for determining soil structure and moisture.

Spade: Used to manually collect samples.
Bucket: Used to mix and homogenize collected soil samples before laboratory testing.
Sample Bags: For storing and transporting soil samples. Bags must be labeled with details like location, depth, date, etc.
Measuring Tape: Helps ensure consistent sampling depth.
GPS Device: For recording sampling locations accurately.

Soil Sampling Techniques

Random Sampling: Soil samples are taken randomly from the field. Useful for uniform fields without significant variability.
Grid Sampling: The field is divided into grids (e.g., 1-acre blocks), and samples are collected from each. Allows for spatial analysis of soil variability.
Zonal Sampling: Field is divided based on visible differences like slope, crop growth, or soil type. Helps target management practices.
Stratified Sampling: Soil is sampled from specific layers or horizons (e.g., topsoil vs. subsoil). Provides insight into nutrient

S. No.	Method	Field Size	Variability	Cost	Accuracy	Best Use
1.	**Random Sampling**	Small to Medium	Low to Moderate	Low	Moderate	When the field is fairly uniform and unbiased sampling is needed
2.	**Systematic Sampling**	Medium to Large	Low	Low to Moderate	Moderate to High	When field variation follows a regular pattern (e.g., uniform fields)
3.	**Stratified Sampling**	Large	High	Moderate to High	High	When field has distinct zones or variability (different soil types, slopes, etc.)
4.	**Composite Sampling**	Any	Moderate	Low	Moderate	When average field values are needed for general fertility status
5.	**Grid Sampling**	Large	High	High	Very High	For precision agriculture and detailed spatial variability mapping
6.	**Cluster Sampling**	Large	Moderate	Moderate	Moderate	When population is spread over wide area and logistical ease is needed
7	**Purposive Sampling**	Any	Variable	Low	Low	When sampling is based on expert knowledge or specific site interest

distribution and structure.

Composite Sampling: Several subsamples from different spots are combined to create one sample. Reduces testing cost while averaging field variability.

Systematic Sampling: Samples are collected at fixed intervals or in a pre-determined pattern. Useful for detecting trends across larger areas.

Best Practices for Soil Sampling

a.) Sample at consistent depth, typically 0–15 cm for nutrient analysis.

b.) Avoid areas that are not representative, like near roads, fences, or trees.

c.) Clean tools between samples to prevent cross-contamination.

d.) Label samples clearly, including field ID, depth, and date.

e.) Collect enough soil, usually 0.5 to 1 kg per sample for laboratory testing.

f.) Mix samples thoroughly when making a composite sample.

Conclusion:

Soil sampling is both a science and an art, requiring proper tools, standardized procedures, and attention to field conditions. Using the right tools like augers, probes, and containers, along with techniques such as grid, composite, or zonal sampling, ensures that soil analysis accurately reflects field health and guides better crop management.

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ZEOLITES FOR CLIMATE-SMART AGRICULTURE: CARBON SEQUESTRATION AND SOIL IMPROVEMENT

Zeolites—natural or synthetic microporous aluminosilicates—act as ecosystem engineers in agriculture, offering nutrient retention, slow release, water holding, heavy-metal immobilization, and soil carbon benefits. This review examines mechanisms and evidence showing their role in climate-smart farming through improved soil properties, higher yields, reduced nitrogen losses and greenhouse gas emissions, and enhanced carbon sequestration, drawing on both laboratory adsorption studies and long-term field/mesocosm trials.

Image Courtesy: Google

1 Introduction

The escalating challenge of climate change, coupled with the imperative to ensure global food security, demands transformative approaches to agriculture. Conventional farming practices often contribute to environmental degradation through greenhouse gas emissions, nutrient leaching, and soil quality decline. In this context, climate-smart agriculture emerges as a critical paradigm, seeking to simultaneously achieve three objectives: increased productivity, enhanced resilience to climate change, and reduced agricultural carbon footprint. Achieving these goals requires innovative technologies and amendments that can work synergistically with natural soil processes. Among the most promising solutions is the application of natural Aluminosilicate minerals known as zeolites, which offer a multifaceted approach to improving agricultural sustainability. Zeolites are crystalline, micro porous minerals with a unique honeycomb-like structure that has attracted significant scientific interest for their remarkable properties as molecular sieves, ion exchangers, and catalysts. While traditionally utilized in industrial applications such as chemical processing and water purification, zeolites are increasingly finding value in agricultural systems, particularly as nations worldwide strive to achieve carbon neutrality.

This article comprehensively examines the role of zeolites in climate-smart agriculture, with a specific focus on their potential for carbon sequestration and soil improvement, while incorporating relevant research from the Indian context. (Lal, R., 2004, Tao et al., 2024, Williamson)

2 The Science of Zeolites: Structure and Properties

2.1 Fundamental Characteristics

Zeolites have a rigid three-dimensional crystalline framework of silicon, aluminum, and oxygen tetrahedra, forming cavities and channels under 2 nm. Substitution of silicon with aluminum creates negative charges balanced by exchangeable cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), giving them high cation exchange capacity and agricultural value. Clinoptilolite is the most widely used type, valued for its CEC, abundance, and affordability. Variations in pore size, channel connectivity, and cation composition determine suitability for specific uses. Their structural stability ensures persistence in soil, resisting microbial breakdown and providing long-term benefits in nutrient retention, water holding, and soil improvement *(Grant; Tao et al., 2024; Bogdanov et al., 2009)*.

Types of Zeolite

Zeolites used in agriculture span natural, synthetic and surface-modified varieties; relative suitability depends on goals (nutrient retention, water holding, or gas adsorption). The table summarizes practical differences and typical applications.(Cataldo, et al., 2023).

Clinoptilolite, a natural zeolite with high cation exchange capacity and strong ammonium retention, is widely used as a soil conditioner, for slow-release nitrogen supply, and for immobilizing heavy metals.

Chabazite, another natural zeolite, often rich in potassium, offers good drainage and water retention, making it useful for alleviating water stress, supplying K, and in particle film foliar applications.

Engineered or modified synthetic zeolites, with functionalized surfaces or ion-exchanged cations, are designed for targeted gas or nutrient selectivity, supporting CO_2 adsorption research, customized slow-release fertilizers, and enhanced sorption performance.

2.2 Mechanisms of Action in Soil Systems

The agricultural benefits of zeolites derive from several interconnected mechanisms:

- **Cation Exchange Capacity (CEC):** Zeolites' negatively charged framework holds nutrient cations like NH_4^+ and K^+, boosting CEC, reducing leaching, and extending nutrient availability—cutting the need for frequent fertilization *(Lal, 2004)*.

- **Molecular Sieving:** Zeolites' honeycomb pores (0.3–1.0 nm) selectively absorb molecules by size and polarity, improving soil aeration and trapping gases like ammonia and CO_2 while excluding larger molecules.

- **Water Retention:** Zeolites store up to 60% of their weight in water, releasing it slowly to roots and greatly improving water-holding capacity, especially in fast-draining sandy soils *(Mondal et al., 2021)*.

3 Zeolites in Carbon Sequestration

3.1 Direct Carbon Capture and Storage

Zeolites possess a porous, cation-rich structure that enables strong electrostatic interactions with carbon dioxide (CO_2), owing to CO_2's high quadruple moment. Their surface electric fields—originating from ionic frameworks—make them effective for CO_2 separation from gas mixtures like flue gas and ambient air. While traditionally applied in industrial capture, this mechanism extends to agricultural soils, where zeolites can adsorb CO_2 from the soil atmosphere, forming in-situ carbon sinks.

A key phenomenon, the "gating effect," enhances this potential: certain zeolites undergo structural shifts triggered specifically by CO_2, allowing selective adsorption over gases like N_2 or CH_4. This CO_2-specific interaction under typical soil conditions reinforces the role of zeolite-amended soils in carbon sequestration. *(Mondal et al., 2021; Lal, 2004)*

3.2 Indirect Contributions to Carbon Sequestration

Beyond direct CO_2 adsorption, zeolites contribute indirectly to carbon sequestration through multiple pathways:

Reduced Fertilizer Manufacturing Emissions: Zeolites boost nutrient use efficiency, cutting synthetic fertilizer needs and lowering the carbon footprint of crop production. Regional reviews report nutrient leaching reductions of 65–86% *(Vaccari et al., 2021)*.

Enhanced Soil Organic Matter: Zeolite amendments enhance plant growth and root biomass, boosting carbon inputs to soil. Their porous structure helps stabilize organic carbon and slow mineralization. Integrating zeolites with aggregate-stabilizing microbes ("zeo bio") can further reduce decomposition and improve carbon retention in peat and degraded soils *(Gaikwad & Warade, 2024)*.

Nitrogen Management and Nitrous Oxide Reduction: Zeolites capture ammonium from fertilizers, slow its conversion to nitrate, and cut nitrous oxide emissions—nearly 300 times more potent than CO_2. By releasing nitrogen gradually, they boost efficiency and reduce leaching. In maize, pairing zeolite with green manure and optimized management lowered N_2O emissions by altering microbial pathways *(Saini et al., 2018)*

Clinoptilolite addition improves water retention, reduces nutrient leaching, and increases yield — typical yield gains reported range widely (e.g., 10–35% with 10 t ha−1 zeolite applications across rice, barley, maize and Soybean crop systems), particularly on Coarse or low-CEC soils where zeolite effectively raises the effective CEC and nutrient retention. (Zhao et al., 2023, Chatterjee, S., 2021)

Modified zeolites and zeolite–biochar hybrids offer enhanced heavy metal adsorption, lowering bioavailability while merging biochar's long-term carbon stability with zeolite's strong ion-exchange capacity. This synergy can alter biochar recalcitrance, immobilize nutrients, and serve as an integrated amendment for contaminant removal alongside soil carbon building *(Gondek & Hersztek, 2021)*

Studies show agronomic benefits across a wide application range—from 0.5–5 t ha^{-1} for engineered or nutrient-loaded zeolites in horticulture to 5–20 t ha^{-1} in field-scale conditioning. Optimal rates depend on soil texture, baseline CEC, and target outcomes, whether improving water retention or boosting long-term SOC *(Kalita et al., 2020)*.

Field and crop studies: foliar or soil applications of zeolite particle films reduced sunburn and yield loss in grapevine trials and improved drought resilience in several horticultural trials.

- **Vineyard outcomes Canopy-** applied zeolite plus irrigation reduced berry sunburn and yield loss in Red Italian Wine grape trials, demonstrating an agronomic climate-adaptation use (Allegro, G et al., 2024)
- **Nano-zeolite** findings Short-term pot/greenhouse trials with nano-zeolite reported physiological improvements in strawberry and other crops, indicating potential for enhanced nutrient delivery at low doses (Zeinalipour, A., & Saadati, S.,2024).

Emissions mitigation: Synthesis from residues and circular economy Converting agro-industrial residues (coal ash, rice husk ash, sugarcane ash) into zeolites is being explored to lower costs and embed zeolite use into circular value chains (Izidoro, et al., 2023)

4 Soil Health and Agricultural Productivity Enhancement

4.1 Improvement of Soil Physical and Chemical Properties

Zeolite amendments improve soil quality through physical and chemical pathways. They enhance structure by increasing porosity and reducing compaction, boosting aeration and water infiltration—benefiting clay soils prone to waterlogging and sandy soils with low water retention. Their high water and nutrient-holding capacity supports seed germination and root growth. Chemically, zeolites raise cation exchange capacity, buffer acidity, and immobilize heavy metals such as Pb, Cd, and Zn, making them effective for both fertility improvement and remediation of contaminated land, ***Viz.*** **Soil pH and dose effects:** soil pH increases from 7.05 to 8.12 with 7.5 t ha−1 zeolite in specific trials. *(Mampton, 1999)*.

4.2 Nutrient Use Efficiency and Crop Yield

Zeolite amendments improve nutrient retention and crop yields by selectively adsorbing and slowly releasing potassium and ammonium. In paddy rice, 5 t ha^{-1} zeolite with half the usual K fertilizer increased yields by 6.4%, while similar trials cut N fertilizer use by 33% without yield loss. This slow-release action maintains nutrient availability, reduces leaching, and lowers environmental impacts in intensive cropping systems. (Bahmanzadegan, F., & Ghaemi, A. 2023).

5 Indian Context: Research and Applications

5.1 Zeolite Synthesis from Fly Ash

India's coal-fired power plants generate vast amounts of fly ash, prompting research into its conversion into zeolites for both waste management and agriculture. In Gujarat, fly ash was fully transformed into crystalline 13X zeolite via NaOH fusion (500–600 °C) and hydrothermal treatment, yielding a 430 m²/g surface area and high metal adsorption capacity, especially at acidic pH. This approach addresses disposal challenges while producing tailored soil amendments for improvement and heavy metal remediation. (Izidoro, et al., 2023)

5.2 Relevance to Indian Agricultural Challenges

Indian agriculture faces declining soil health, nutrient imbalances, and water scarcity. Zeolite amendments can ease moisture stress in rainfed systems, cut fertilizer needs for smallholders, and improve sandy soil structure. Fly ash–derived zeolites also adsorb heavy metals, offering solutions for contaminated soils near industrial zones

6 Practical Implementation and Considerations

6.1 Application Methods and Rates

Zeolite rates depend on scale, soil, and goals. In field agriculture, 450 kg/ha maintains soil quality, while up to 3,600 kg/ha aids degraded soils or boosts water retention—lighter doses suit fertile soils, heavier for coarse or low-CEC soils. In gardens, use 1 lb/yd² or 5% in potting mixes; for new lawns, mix a 0.5 in layer into topsoil. Add ~2 lb to compost to speed decomposition, cut odors, and retain nitrogen. (Bahmanzadegan, F., & Ghaemi, A. 2023).

Examples of Recent Indian Market Zeolite Prices : Exporters India supplies bulk agricultural zeolite powder (₹15–₹20/kg, MOQ ~20 t), basic grade with unspecified purity. Astrra Chemicals in Chennai offers aquaculture-grade granules (₹41/kg, MOQ 100 kg), likely purified thus costlier. Kutch Bento Clay Co. sells general agricultural use powder at ₹7,000/t (MOQ 10 t), low-cost option whereas, Bengal Agro Industries provides agricultural granules at ₹12/kg (large MOQ), basic grade suitable for general soil conditioning.

6.2 Soil-Specific Considerations

Zeolite performance depends on soil type—sandy soils often see the greatest gains in nutrient and water retention, while clay soils benefit mainly from improved aeration and reduced compaction. A soil test helps determine suitability and optimal rates. Particle size also matters: fine particles offer higher adsorption but risk wind loss, whereas coarse particles are more durable for long-term improvement.

In SHD climates, Vertic Haplustalfs evolve toward Typic Haplusterts. **Ca-rich zeolites** maintain Vertisols by supplying bases and preventing smectite-to-kaolinite transformation; once depleted, acidic Vertisols shift to Alfisols and eventually base-poor Ultisols. In Ca-zeolite-free systems, Alfisols progress to Ultisols faster. Ultisols remain kaolin-dominated due to silica insolubility in acidic conditions.

In SAT Central India, optimum cotton yield is achieved in non-sodic soils (ESP < 5) with sHC ≥ 20 mm h^{-1}. whereas 50%Yield Reduction in Sodic Vertisols observed in Vertisols with ESP > 5 and sHC < 10mm h^{-1}, in this context Ca-Zeolite plays an important role as it regulate ESP and pH They prevent a rise of (ESP > 15) and pH, maintaining more favorable conditions for plant growth., raise Ca/Mg ratios, improve hydraulic properties, and enable sodic shrink-swell soils to support rainfed crops. They act as **ecosystem engineers**, enhancing soil function. (Pal, Dilip., 2022).

7 Conclusion and Future Directions

Zeolites offer a versatile, science-backed route to climate-smart agriculture, improving nutrient and water efficiency, enhancing soil health, cutting greenhouse gas emissions, and aiding carbon sequestration. Scaling their impact will require locally calibrated field trials, integration with organic inputs, testing of modified carriers, and multi-season monitoring of GHG fluxes and SOC. With targeted research and adoption, zeolites can help deliver the triple win of higher productivity, greater resilience, and meaningful climate mitigation.

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AN INTRODUCTION TO BIOSPECKLE IMAGING FOR SUSTAINABLE AGRICULTURAL SYSTEMS

1. ABSTRACT

Biospeckle imaging is a non-destructive optical method that measures biological activity in agricultural materials by detecting temporal variations in laser speckle patterns. These fluctuations reflect internal processes, such as respiration, water movement, and metabolic activity. This technique provides a rapid means of evaluating seed vigour, fruit ripeness, and plant stress without the need for chemical or physical alterations. By generating quantitative activity maps, biospeckle imaging supports sustainable agricultural practices through the early detection of quality loss and efficient resource use. This article summarises the basic working principles, common analytical approaches, and representative applications in crop and post-harvest systems. The potential of biospeckle imaging as a practical monitoring tool for precision and sustainable agriculture is also discussed.

Keywords: Biospeckle Imaging, Non-Destructive Testing, Quality Assessment, Optical Sensing, Sustainable Agriculture

2. INTRODUCTION

Agriculture increasingly demands non-destructive, rapid, and sensitive methods for monitoring plant status, seed vigour, disease, stress, and postharvest quality. Optical imaging techniques, such as hyperspectral imaging, multispectral imaging, fluorescence imaging, and thermal imaging, have been widely studied. Among these, biospeckle imaging (also called dynamic laser speckle or dynamic speckle imaging) has attracted attention because it can probe *internal activity* (microscopic motions and metabolic activity) rather than merely static structural or spectral features.

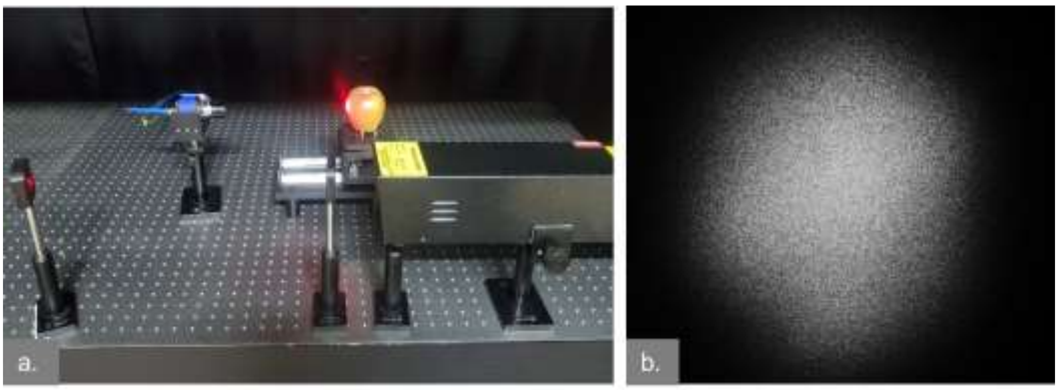

Figure 1: (a) Biospeckle Imaging Setup and (b) typical speckle pattern of fruit

When a coherent light source (a laser) illuminates a rough surface (such as plant tissue, seeds, or fruit), the scattered light interferes, producing a granular speckle pattern at the detector (Figure 1). If the illuminated material is static, the speckle pattern remains stable; however, if internal particles, fluids, or structures undergo motion (due to metabolism, cytoplasmic streaming, and diffusion), the speckle pattern fluctuates in time (dynamic speckle). The rate and character of these fluctuations (the biospeckle signal) can be correlated with biological activity in the sample (e.g. vitality, aging, and stress). The following sections outline the technical basis, typical instrumentation and signal processing, existing agricultural applications, challenges, and future directions.

3. PRINCIPLES, METRICS, AND SIGNAL PROCESSING

3.1 Fundamentals of Speckle and Biospeckle

- When coherent light illuminates a rough or scattering object, the scattered waves interfere, producing a speckle pattern of bright and dark granular spots in the observation plane.
- If internal scatterers or refractive index variations move, the phase relationships change, and the speckle pattern "boils" or fluctuates over time.
- The temporal fluctuations are analyzed to yield quantitative descriptors of "activity."

The main goal is to map how dynamic a pixel or small area of the sample is: more fluctuation means higher internal motion (hence more active tissue), and lower fluctuation suggests dormancy, aging, or damage.

3.2 COMMON METRICS AND ALGORITHMS

Over the decades, several statistical/signal processing methods have been developed to convert raw speckle image sequences into indices or activity maps. Table 1 shows the classic and commonly used algorithms

Table 1: Commonly used statistical/signal processing methods for biospeckle patterns

Method / Metric	**Principle**	**Strengths / Uses**	**Limitations**
Temporal contrast	For each pixel, compute standard deviation / mean over time	Simple, widely used	Sensitive to noise, choice of window size matters
Fujii's method	Normalized sum of sequential frame differences	Enhances contrast in active vs inactive zones	May saturate in high-activity areas
Generalized Differences (GD)	Recursive differences across frames to amplify changes	Good sensitivity to subtle motion	Possible saturation, computational cost
Absolute Value of Differences (AVD)	Accumulate absolute differences between frames	Easy and robust	May mix contributions from noise / drift
Time History of Speckle Pattern (THSP) + Co-occurrence Matrix (COM) analysis	Build a matrix tracking pixel intensity over time, then compute autocorrelations or joint histograms	More complete statistical descriptors, spatial–temporal relationships	More complex computation, needs calibration
Laser speckle contrast analysis (LASCA)	From a single (or short-exposure) image, compute contrast (std/mean) in local windows	Faster, real-time possibility	Lower resolution in dynamic range, loses temporal sampling

These approaches produce either global indices (for the entire sample) or spatial maps (activity maps or heat maps) that visualise the spatial distribution of biological activity. A properly calibrated biospeckle system can generate a map showing which regions of a leaf, fruit, or seed are more active and can yield numerical indices of vigour or change over time.

The key technical considerations are as follows:

- Frame rate/exposure time: the sampling must be sufficient to capture relevant fluctuations but avoid aliasing or motion blur.
- Number of frames / measurement duration: More frames generally improve the signal-to-noise ratio but at the cost of time.
- Choice of pixel or patch region: individual pixels or averages in local windows may be tracked.
- Normalisation and calibration: Calibration or baseline subtraction is often required to compare different samples or conditions.
- Filtering (temporal/frequency domain): Sometimes used to separate fast motion from slower drift or noise (e.g. water diffusion).

4. APPLICATIONS IN AGRICULTURE

In agriculture (including crop science, postharvest, and seed science), biospeckle methods have been explored in several domains. The following are representative applications and key findings.

- Seed viability, vigour, and germination prediction: Seed vigour testing distinguished live vs. dead seeds in bean (Phaseolus) and pea seeds (Pisum) coffee seeds (Coffea arabica), and germination progression.
- Fruit Quality, ripening, defect detection, and Shelf-life: It has been applied to monitor fruits and vegetables to assess quality, detect bruises or internal defects, and monitor aging of fruits and vegetables.
- Stress detection, water stress, and plant physiology monitoring: Plant stress (e.g. drought, nutrient deficiency) is detected by capturing changes in internal metabolism or fluid movement. More generally, biospeckle measurements may capture changes in cytoplasmic streaming, stomatal behaviour, or vascular flows, enabling the early detection of physiological changes before macroscopic symptoms.
- Plant parasite/pest/pathogen interaction and bioactivity screening: Because biospeckle captures motion/biological activity, it has also been used to study microbial and nematode activity in agricultural settings.
- Plant breeding and phenotyping: Biospeckle is sensitive to subtle internal dynamics and has potential in plant breeding/phenotyping, especially in monitoring physiological or stress traits.

5. ADVANTAGES, LIMITATIONS, AND TECHNICAL CHALLENGES

5.1 Advantages

i. Non-destructive/label-free: No dyes or invasive probes are required, preserving the sample integrity.

ii. Sensitive to internal activity: Captures motion at the micro-level (diffusion, streaming, cytoplasmic flows), which are often precursors to macroscopic changes.

iii. Rapid and real-time potential: Depending on the setup and algorithms, measurements can be performed in minutes or seconds.

iv. Spatially resolved: Yield maps showing heterogeneity inside seeds, leaves, or fruits.

v. Relatively low-cost optics: A coherent light source (laser diode) and standard cameras suffice in many setups.

1.2 Limitations and challenges

i. Calibration and standardisation: Different samples (species and tissue types) have different scattering, absorption, moisture, and structural properties. A given bio-speckle index must be calibrated for each sample class.

ii. Confounding influences (especially water/moisture dynamics): Moisture diffusion, evaporation, or changes in water content also induce speckle fluctuations, which may confound the biological activity signal.

iii. Signal-to-noise, drift, and instrument stability: Mechanical drift, vibration, ambient light, and thermal variations can perturb measurements.

iv. Data processing complexity: Advanced metrics (THSP and co-occurrence matrices) require more computation. Real-time mapping and automation remain challenging in several cases.

v. Limited penetration depth: Because coherent light typically probes only the surface or near-surface layers in scattering media, biospeckle is more sensitive to superficial activity. Internal deeper regions (e.g. deep inside seeds or thick tissues) may be less well sampled.

vi. Lack of large-scale field demonstrations: Many reported studies are laboratory or semi-controlled studies. Scaling to fields, sensor networks, or industrial seed labs remains to be fully proven.

vii. Interpretation ambiguity: Because the biospeckle signal is an aggregate of many microscopic motions, attributing changes to specific biological processes (e.g. metabolic rate, cell division, pathogen action) requires complementary validation.

Biospeckle imaging holds promise as a useful tool in precision agriculture for assessing seed lots, monitoring crop stress in situ, quality control of produce, and phenotyping in breeding programs.

6. CONCLUSION

Biospeckle imaging is a relatively mature but still evolving optical method that captures the internal dynamic activity within biological samples. In agriculture, its appeal lies in its non-destructive nature, sensitivity to subtle internal motion, and potential for mapping vitality and stress. Significant results have already been obtained in seed quality evaluation, fruit quality and defect detection, stress monitoring, and pathogen/parasite bioactivity screening. However, to fully realise its potential in real-world agricultural settings, the challenges of calibration, standardisation, noise mitigation, field deployment, and interpretability must be addressed. Advances in hardware, algorithms, multimodal fusion, and large-scale validation should help mature biospeckle into a practical tool for use in precision agriculture.

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ROSE APPLE- A STORE HOUSE OF NUTRACEUTICALS

Introduction

Rose apple is a minor fruit of our country, which is still confined to the backyard gardens. The rose apple, *Syzygium jambos* (syn. *Eugenia jambos* L.), is a large shrub or small to medium in size tree, known to grow originally in South-east Asia, but now widely distributed in the tropics. It belongs to family Myrtaceae. It is also popularly known as Malabar plum or Plum rose. In India, it has been regarded as an ornamental plant in many places, due to its showy flowers. Fruits are eaten fresh, which possess typical rose like flavor. The fruits are very delicious and refreshing, but only limited to local markets (Majumdar, 2002). The pulp has spongy texture which is neither very hard nor very acerbity.

The flowering mainly occurs during March-April under Indian condition. The flowers are creamy white or greenish white in colour and about 5-10 cm in diameter. Each flower consists of about 300 conspicuous stamens (4 cm long), a 4 lobed calyx and 4 greenish white concave petals. Usually 4 or 5 flowers appear together in terminal clusters. Chantaranothai and Parnell (1994) reported that, rose apple was a self compatible and self pollinated species of *Syzygium*. They also reported that, seed set occurs *via* apomixes, autogamy and geitonogamy and also it is enhanced by pollination.

Varied shape of fruit exists in rose apple *i.e*. from nearly round or oval to slightly pear shaped. Each fruit is capped with a prominent green hard calyx. Skin of the fruit is smooth, thin and pale yellow to whitish colour with or without pink blushed, covering a crisp, mealy, dry to juicy layer of yellowish sweet flesh resembling the flavor of a rose. The seed cavity is hollow and contains about 1 to 4 globular, brown, roughly coated seeds. Seeds are loosely attached with the inner wall of seed cavity and easily rattled down upon shaking (Binggeli, 2005).

Basically, rose apple is a tropical plant. It can grow well in the temperatures ranging from 25-32^{0}C. It also flourishes well in subtropical climate. Its cultivation ranges upto an elevation of about 1350m. It does well on the banks of canals and streams, but also has the ability to tolerate the semi-arid conditions. But the prolonged dry spell seems to reduce the yield of the plant considerably. A deep red loamy soil is considered ideal for its cultivation. However, it can thrive well on different soil types also. A relatively cooler temperature towards ripening enhances total soluble solids and favours accumulation of anthocyanins in rose apple.

Polyembroyonic seeds are commonly found in case of rose apple. It is easily propagated from seeds. But, production of non-uniform seedlings is also observed in some cases. In India, its vegetative propagation has also been tried in order to produce dwarf plants and a qualitative plant stand. The hard wood and semi hard wood cuttings give poor or no rooting. Hence, air layering can be followed for commercial propagation, where a 60% success rate has been reported, when treated with 1000ppm NAA. Budding is also a failure in rose apple propagation. However, veneer grafting in July spring flush of scion on 1 year old rootstock has shown somewhat success rate.

Nutritional composition and uses

- Rose apple can be consumed both fresh as well as processed forms, however in India, the fresh form is usually preferred.
- The fruits can also be used for canning, jellying or for candying.
- In Jamaica, fruits are stewed with heavy sugar syrup for preparation of candy.
- The syrup prepared from rose apple is used to make refreshing drink and also used for medicinal purposes (Prashanta *et al*., 2003).
- It contains protein 0.5-0.7 g, fibre 1.1 – 1.9 g, sugar 4.58%, iron 0.45-1.2 mg, and calcium 29-45mg per 100g of edible portion (Morton, 1987 and Majumdar, 1979).
- Vitamin B_1: 0.01-0.19mg, Vitamin B_2: 0.02-0.05 mg, Vitamin C: 3-37 mg and energy of 56 KJ is present in 100g of edible portion (Morton, 1987 and Majumdar, 1979).

Health benefits and medicinal properties

- Aqueous, methanol and ethyl acetate extracts of rose apple leaves from Guatemala have been shown to possess anti-inflammatory activity (Slowing *et al*., 1994a).
- Several flavonoids were isolated among which myricetin and quercetin are the two important showing immune functions in human system.
- Rose apple possess significant antibacterial, antifungal, analgesic and anti-inflammatory properties.
- In Indian traditional system of medicine, the decoction of the fruit and leaves are traditionally used as a diuretic and an

expectorant hoarseness (Mohanty and Cock, 2010).

- It is also used in treatment of tooth ailments, sore eyes and in rheumatism.
- In Indo-China, the flowers are used to reduce fever, and the seeds in the treatment of diabetes, diarrhea and dysentery hoarseness (Mohanty and Cock, 2010).
- The decoction of bark is believed to relieve asthma, bronchitis and hoarseness (Mohanty and Cock, 2010).
- High fiber content of rose apples makes them very good for regulating the passage of food through your digestive tract, relieving constipation.
- For hundreds of years, rose apple decoctions have been used as a diuretic substance, which helps clear out liver and kidney toxicity, while also boosting the overall health and metabolic efficiency of the body.
- It has also been claimed that, rose apples are having anti-cancerous potential reducing the risk of breast and prostate cancer.
- These also play an important role in preventing rise of cholesterol level in blood, leading to a lower risk of artherosclerosis.
- It is very much essential to include rose apple in food basket for good cardio-vascular health.
- In addition, it is loaded with powerful antioxidants, that enables the human kind to fight against several deadly chronic diseases through inclusion in daily food basket.

Conclusion

There are very few fruits, which have rose like aroma except rose apple. Hence, Selection of germplasm in rose apple having high volatile component along with high pulp content may also increase the popularity of this crop in urban areas. Emphasis should also be given upon value addition of this crop. Evidence based study is required to exploit its medicinal properties. Besides, other vitamins and minerals are also available in fair amount which could meet the dietary demand of rural and urban people.

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INSECTS AS NATURE'S WEED WARRIORS: THE POWER OF BIOLOGICAL CONTROL

Abstract:
Weeds are a critical threat to agricultural ecosystems worldwide, causing the loss of millions of cultivated hectares annually and leading to significant losses in crop productivity, ecosystem balance, and economic value. The unbridled and unrestrained usage of broad-spectrum chemical herbicides has induced the evolution of herbicide-resistant weed biotypes, a reduction in natural predator diversity, and soil, water, and food supply networks' pollution. The adverse impacts thus underscore the need for weed control tactics that are ecologically benign and environmentally friendly. In this light, insect-related biological control emerges as a scientifically plausible and environmentally conscious alternative to conventional chemical control mechanisms. The approach involves intentional releases of host-specific natural antagonists, such as weedy-feasting insects and pathogens, to lower weeds' population levels to non-harmful thresholds while simultaneously safeguarding valuable plant species. Furthermore, utilization of advanced technologies such as nanotechnology, biotechnology, as well as molecular approaches creates promise for enhanced impacts and improved performance in terms of efficiency for both biological control agents and cropping operations. Intensified cooperation among governmental organizations, research organizations and private sectors is needed to enhance awareness creation, support for conservation initiatives and popularization of biological control's large-scale usage with the overall aim of achieving sustainable as well as resilient agricultural ecosystems through reduction of chemical herbicides' and their toxic residual matter's adverse impacts on human, animal, and ecosystems' well-being.
Keywords: Weed killers, noxious weed, perennial weed, biological control of weeds, biological agents, augmentation, and conservation

Introduction:
Over the past few decades, increasing concern about the environmental and health risks of pesticide use has driven efforts to lessen reliance on chemical control measures which exerts toxic residues in foods, water, air, and soil. Chemical pesticides also give big impact on yield of crops through pesticide poisoning, pest resistance to certain pesticides, pests resurgence, elimination of natural enemies and disruption of ecosystem. In Integrated approaches, there are several methods including physical, chemical, mechanical and biological control strategies which have been adopted to manage invasive weeds population. Among them most costly approaches are physical and chemical control, whereas biological control of weed technique is considered as a budget friendly, long term and safe for environment.

Biological control depends on predation, parasitism, competitive plants, disease organisms, or other animals to prevent and manage their growth rate. Weeds cannot be fully eradicated by biological management practices, but their populations can be checked (Telkar *et al.*, 2015). Biological control is mostly target specific viz., weed population, has no residual effects and not harmful to agricultural crops. Recently, Modern agriculture faces stagnating yields and rising ecological risks from excessive chemical use. Consequently, using biological control can serve as a sustainable alternative for effective weed management. Weed killers or simply called as insect biological agents destroy destructive weeds population and dangerous vegetation. In India, classical biological control has achieved the highest success rate against aquatic weeds (55%), followed by homopterous pests (46.70%) and terrestrial weeds (23.80%) (Bade *et al.*,2022).

Historical background:

1795: The first successful instance of classical biological control in India was recorded with the introduction of the cochineal insect *Dactylopius ceyonicus* from Brazil to manage infestations of prickly pear (*Opuntia* spp.)

1977: Beginning of "All India Co-ordinated Research Project on Biological Control of Crop Pests and Weeds".

1993: The project renamed as "Project Directorate of Biological Control (PDBC), Bangalore.

2009: PDBC renamed as National Bureau of Agriculturally Important Insects (NBAII).

2014: NBAII renamed as National Bureau of Agricultural Insect Resources (NBAIR).

Overviews of biological control:

The action of parasitoids, predators, or pathogens in maintaining another organism's population density at a lower average than would occur in their absence" (Paul De Bach, 1964). Biological control is defined as the intentional use of living organisms, frequently referred to as natural enemies, to manage pest populations. Most biological control agents are mass-reared, introduced, and disseminated by humans to successfully control the target pest. The term 'biological control' was first used by Smith in 1919 to describe the use of natural enemies in pest suppression.

Methods of biological control:

1. Introduction or classical biological control: It is the intentional establishment and release of predators or parasitoids in a new region where neither is native nor originally occurred. After successful establishment of natural enemies, it typically persists in the ecosystem and contribute to sustained regulation of pest populations.

2. Augmentation: This is a biological control strategy that involves the supplemental release of natural enemies to increase their population density and enhance pest suppression in a target area. It is applied when existing populations of a natural enemy are not sufficient to achieve effective control.

- **Inoculative releases:** Entail single releases of a massive number of organisms at a certain season such that natural enemies multiply and increase in number during the growing season. Hence, control is forecast from such offspring as well as subsequent generations, as opposed to that from the initial organisms released.

- **Inundative releases:** Consist of periodic releases of mass-reared natural enemies when the pest populations build up to economically damaging levels. In this strategy, the individuals released are responsible for the suppression, and no reproduction or establishment in the ecosystem is expected. Further releases are made only when the pest resurgence takes place and it is permanent in nature whereas inoculative release is temporary.

3. Conservation: Refers to strategic actions to preserve and enhance populations of natural enemies already present in an ecosystem. This involves environmental manipulations, modifications of agricultural practices, and the avoidance of pest control measures that are harmful to beneficial organisms.

Table No. 1. List of weed killers with its imported country and introduction year with associated weeds and its type

Sl No.	Weed name & type	Weed killer name	Taxonomical status	Imported country into India	Introduction year
1.	Parthenium (*Parthenium hysterophorus*) Noxious weed	*Zygogramma bicolorata*	Order: Coleoptera Family: Chrysomelidae	Mexico	1983
2.	Water hyacinth (*Eichhornia crassipes*)	*Neochetina bruchi*	Order: Coleoptera Family: Curculionidae	Argentina via USA	1982/83
		N. eichhorniae	Order: Coleoptera Family: Curculionidae	Argentina via USA	1983
	Aquatic noxious weed	*Orthogalumna terebrantis*	Order: Acari Family: Orthogalumnidae	Argentina via USA	1986
3.	Lantana weed (*Lantena camara*)	*Epinotia lantanae*	Order: Lepidoptera Family: Tortricidae	Mexico	1919
	Perennial noxious weed	*Lantanophaga pusillidactyla*	Order: Lepidoptera Family: Pterophoridae	Mexico	
4.	Prickly pear (*Opuntia spp.*) Perennial noxious weed	*Dactylopius opuntiae*	Order: Hemiptera Family: Dactylopidae	USA via Sri Lanka via Australia	1926
5.	Crofton weed (*Ageratina adenophora*) Perennial weed	*Procecidochares utilis*	Order: Diptera Family: Tephritidae	From Mexico via Hawaii, USA via Australia via New Zealand	1963

Characteristics of weed killers:

1. It should kill target weed population without harming crops or beneficial organisms.
2. It should not pose any threat to cultivated plants or interfere with agricultural production.
3. It can be able to reproduce in large amount without being harmed by natural enemies (Pritamkumari, *et al.*, 2022).
4. It can provide strong control even in small quantities, environmentally safe, economical, biodegradable, rapid activity, long lasting and ease of application.
5. It should be an internal feeder of the weed which can able to check the weed population under economic threshold level.

Biological control agents:

1. **Predators:** Free-living organism, typically larger than its prey, that actively hunts, captures, and consumes other organisms by killing them. E.g., Lady bird beetles, lacewings, dragonfly, damselfly, assassin bug etc.

2. **Parasites:** Organism that lives in or on a host organism, typically smaller in size, and derives nutrients at the host's expense without causing immediate death. Unlike predators, individual parasites generally do not kill their hosts. E.g., Lice, tapeworms etc.

3. **Parasitoids:** An organism that is parasitic only in its immature stages, ultimately killing its host while it completes its development. As an adult, it is free-living and independent of a host. E.g., *Campoletis chlorideae, Bracon brevicornis* etc.

4. **Entomopathogens:** The word entomopathogens is originated from the Greek words "entoma" denotes insect, "pathos" denotes suffering, and "gennaein" denotes to produce. So, Entomopathogens are the microorganisms pathogenic to insect. E.g., Bacteria (*Bacillus thuringiensis*), Fungi (*Metarhizium anisopliae*), Nuclear Polyhedrosis Virus (NPV), Nematodes (*Heterorhabditidae* spp)

5. **Weed killers:** Insect bioagents which are reproduced to prevent weed population by feeding them called weed killers. E.g., *Dactylopius ceylonicus, Prococidochares utilis* etc.

6. **Biorational pesticides:** Pest control substances derived from natural or biological origins, or synthetically produced materials that mimic natural mechanisms, designed to be effective against target pests with minimal ecological disruption *(EPA, 2023; Copping & Menn, 2000)*. E.g., Botanicals (Pyrethrins, Neem oil), Minerals (Kaolin clay), Synthetics (Methoprene) and Biochemicals (Pheromones, Kairomones, Allomones) etc.

Parthenium hysterophorus

Zygogramma biocolorata

***Smicronyx lutulentus* (Coleoptera)**

Eichhornia crassipes

Neochetina bruchi

Lantanophaga pusillidactyla

Orthogalumna terebrantis

Opuntia spp.

Lantana camara

Dactylopius opuntiae

Epinotia lantanae

Dactylopius ceylonicus

Ageratina adenophora

Procecidochares utilis

Advantages and disadvantages of biological control of weed:

Advantages:

1. Ease of application and affordable techniques.
2. It is very much weed host specific that can only kill targeted weeds and keep weed population under control for years.
3. Biological weed control is an environmentally sound and long-term process to control weed ecology.
4. Reduced chemical herbicides resistance.
5. Lower the risk of accidental exposure as it oftens non-toxic to human and any other organisms.
6. It is compatible with integrated weed management such as cultural and mechanical methods.

Disadvantages:

1. Costly and time-intensive task
2. Sometimes it may target crops after weeds depletion process.
3. It maintains weeds population where they can survive on and may not remove weed ecology fully.
4. Once the agent has been introduced to field, it may be quite challenging to check its functionality.
5. Developing effective biological weed control agents requires extensive research, as suitable agents are not available for all weed species.
6. Regulatory and legislative scrutiny which hinder the adoption and application of bioagents.

Conclusion:

Biological control with insects is a long-term, efficient alternative to the use of traditional pest and weed management. Specifically, biological control has relied on the use of both introduced and native natural enemies, whether it be insects that feed on weeds, or other predators, traditionally and currently, in organic or sustainable farming practices. With increasing resistance to chemical pesticides in both pests and weeds, there is a growing necessity to develop and deploy biological control agents. There are numerous developments in areas like nanotechnology, biotechnology, and molecular tools toward both development of improved strains of biopesticides and improving performance of natural enemies. With the specificity, environmental benignity, and safety for users and applicants that these biocontrol agents appear to promote, it seems auspicious to promote and utilize these biological agents. Therefore, collaboration between governments, researchers, and the private sector will be essential to increase awareness, conserve natural predators, and promote biological control for sustainable agriculture.

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SUBCLINICAL MASTITIS: METHODS OF DETECTION, PREVENTION AND CONTROL IN DAIRY ANIMALS

Introduction

Mastitis in cattle is a significant and common disease causing inflammation of the udder, often due to bacterial infections, but sometimes triggered by fungi, viruses, or physical trauma. It is characterized by physical, chemical and usually bacteriological changes in milk and pathological changes in glandular tissues of the udder and affects the quality and quantity of milk (Radostits et al., 2000) It leads to reduced milk yield, alters milk quality, and can result in economic losses due to treatment costs, discarded milk, and premature culling. Mastitis is the costliest disease in dairy production worldwide due to lost milk, treatment, and culling, with the bulk of costs coming from reduced milk yield. Mastitis in cattle is classified based on clinical presentation, duration, and mode of infection transmission. Each classification helps determine the appropriate prevention, diagnosis, and treatment approach.

Classification by Clinical Presentation

This is the most widely used method, based on visible signs and udder inflammation.

- Peracute mastitis: Peracute mastitis in cattle is an extremely severe and rapidly progressing form of mastitis often associated with coliform bacteria such as Escherichia coli and Klebsiella pneumoniae. This type typically occurs just before calving, in early lactation, or under environmental stress like wet weather. It has a rapid onset with severe udder inflammation, fever, depression, dehydration, and toxemia; it is often life-threatening.
- Acute mastitis: Sudden inflammation of the udder with fever, swelling, and abnormal milk (clots, flakes, wateriness)
- Subacute mastitis: Milder udder inflammation, slight milk changes, no systemic illness
- Subclinical mastitis: No visible symptoms; detected by high somatic cell count or CMT test
- Chronic mastitis: Long-standing infection with periodic flare-ups and tissue fibrosis

Classification by Mode of Transmission

- Contagious mastitis: Spread during milking through equipment, milkers' hands, or infected udders. Common pathogens include Staphylococcus aureus, Streptococcus agalactiae, and Mycoplasma bovis
- Environmental mastitis: It is caused by organisms from bedding, manure, or contaminated water, typically E. coli, Klebsiella, and Streptococcus uberis
- Summer mastitis: Occurs during warm months, mainly in dry cows or heifers, and is often transmitted by flies (Corynebacterium pyogenes, Peptostreptococcus indolicus).

Scenario of Mastitis in India

Mastitis is a critical challenge in India's dairy sector, impacting milk yield, farmer income, and livestock health at a large scale. It remains one of the most economically damaging diseases for Indian dairy farmers, affecting both commercial and smallholder operations.

Prevalence and Epidemiology

The overall prevalence of mastitis among Indian dairy cattle is estimated at around 40-45% when both clinical and subclinical cases are considered. Subclinical mastitis is particularly widespread; studies in different Indian regions report prevalence ranging from 30% to over 40% in sampled animals, with clinical mastitis rates between 10% and 18%. Pathogens like Staphylococcus aureus, coagulase-negative staphylococci, E. coli, and Bacillus spp. are commonly isolated from infected cattle. A significantly higher prevalence of SCM was observed in crossbred cows as compared to indigenous cows (Sharma et al., 2018, 2023).

Infection Sources and Transfer

The primary infection sources and routes of transfer for mastitis in cattle are classified as either contagious or environmental. Both pathways contribute significantly to the spread of the disease within herds, especially in the context of improper management and hygiene practices.

Contagious Sources

Infected Udders and Teat Skin: Bacteria like Staphylococcus aureus and Streptococcus agalactiae persistently colonize udders, teat skin, and teat canals, serving as chronic reservoirs of infection. These pathogens are easily transferred during the milking process.

Milking Equipment and Milk Handlers: Teat cup liners, milkers' hands, washcloths, and even flies can transfer bacteria between infected and healthy animals when hygiene measures are lacking.

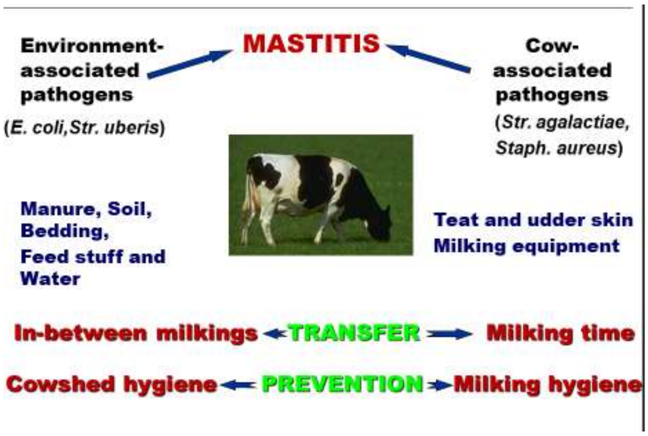
Purchased Animals: Introduction of subclinically infected cows or heifers, especially with Mycoplasma bovis, can introduce contagious mastitis into previously uninfected herds.

Environmental Sources

Bedding and Housing: Pathogens such as Escherichia coli and Streptococcus uberis thrive in manure, wet bedding, stagnant water, and dirty milking or housing environments.

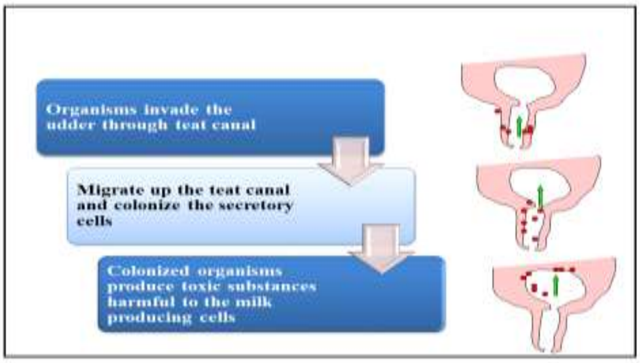
Manure and Organic Matter: Animal feces, organic debris, and contaminated water serve as ongoing sources for environmental mastitis organisms.

Contact with Poorly Cleaned Surfaces: Cows lying on soiled bedding or walking through dirty environments may get their teats contaminated, leading to infection entry via the teat canal



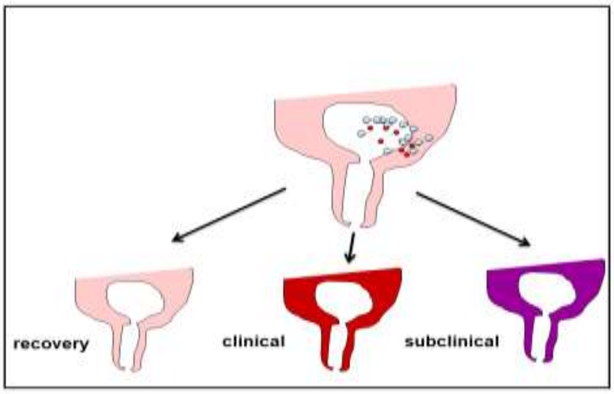
Process of infection

The process of infection in mastitis involves a sequence of microbial invasion, colonization, inflammation, and tissue damage within the cow's mammary gland. The disease progression



depends on the pathogen type, host immune response, and environmental or management conditions.

The cow's immune system sends white blood cells (Somatic cells) to fight the organisms



Methods of Detection of Subclinical Mastitis

Indirect test –

- California mastitis test (CMT)
- Somatic cell count (SCC)
- Electrical conductivity test (EC)
- White side test (WST)
- Sodium lauryl sulphate test (SLST)
- Chloride test
- Catalase test
- Bromothymol blue test (BTB)

Direct Test-

- PCR
- Rennet coagulation test
- Lactose determination test
- Radial immunodiffusion test

Biochemical test-

- Arginase enzyme
- Lactate dehydrogenase (LDH)
- Alcaline Phosphatase (ALP)
- Alanine aminotransferase (ALT)

California mastitis test

The California Mastitis Test (CMT) is a simple, cost-effective, and rapid cow-side diagnostic test used for early detection of subclinical mastitis in dairy cattle. It estimates the somatic cell count (SCC) in milk, which increases in response to mammary infection and inflammation.

How the California Mastitis Test Works

Milk samples from each quarter are mixed with the CMT reagent, which contains a detergent that lyses the white blood cells present in the milk. When somatic cells are lysed, their DNA interacts with the reagent to form a gel-like material whose viscosity increases with the number of cells. The formation and thickness of the gel or precipitate indicate the severity of inflammation:

- No reaction or watery: Negative (healthy quarter)
- Slight thickening: Trace (possible mild mastitis)
- Distinct gel formation: Positive (mastitis likely)
- Strong gel or clumps: Strong positive (severe mastitis).

Somatic Cell Count

The Somatic Cell Count (SCC) test is a widely used diagnostic tool for assessing the presence and severity of mastitis in dairy cattle. It quantifies the number of somatic cells—primarily leukocytes (white blood cells)—present in milk, which increase during infection and inflammation of the mammary gland.

How the SCC Test Works

Milk samples are collected from individual quarters or the whole herd. The SCC is measured using various methods such as direct microscopic counts, flow cytometry, or electronic somatic cell counters. A high SCC indicates an immune response to infection; generally, values above 200,000 cells/ml suggest subclinical mastitis, while higher counts (e.g., >500,000 cells/ml) are associated with more severe or clinical mastitis

No. of cells/ml milk	Interpretation
1 lakh	Healthy udder
2.5 lakhs	Some disturbance
3.0 lakhs	Got infection
> 4 lakhs	Udder is diseased

Electrical Conductivity test

EC is now employed as a routine test for SCM detection .EC is influenced by sodium, potassium, calcium, magnesium, chlorine, and other ions. EC of the milk increases due to an increased conc. of Na^+ and Cl^-. MASTITRON LF 3000 and LF 4000 is the devices used for measurement of EC in milk

White side test

The WhitesideTest (WST) is a simple, rapid, and cost-effective diagnostic method commonly used for on-farm detection of mastitis in dairy cattle. It helps in identifying subclinical and clinical infections by indicating the presence of increased somatic cells and inflammatory changes in milk. Collect a few drops of fresh milk from each quarter onto a clean glass slide or paddle. Add an equal amount (usually 2–3 drops) of 4% sodium hydroxide (NaOH) solution to the milk sample. Mix thoroughly by gently swirling the slide or paddle. Observe for the formation of clots, clumps, or a thickened/gel-like consistency. A positive reaction (formation of visible clots) indicates the presence of excess somatic cells, suggestive of mastitis.

Catalase test

The catalase test is an indirect and practical diagnostic method for mastitis detection in dairy cattle. It measures the amount of catalase enzyme present in milk, which originates mainly from leukocytes (white blood cells) that increase during mastitis and inflammation. Catalase is an enzyme found in somatic cells (especially leukocytes) and reacts with hydrogen peroxide to release oxygen and water. Higher oxygen production (volume above 1.5–2.5 ml) or abundant bubbling is considered abnormal and suggests mastitis.

Bromothymol blue test

The bromothymol blue test is a rapid, chemical-based screening method for detecting mastitis in dairy cattle by assessing changes in milk pH. It is commonly used in resource-limited farm settings and can help identify subclinical mastitis cases alongside other tests drop of bromothymol blue reagent is added to a milk sample, either directly or by using pH indicator paper. The mixture is observed for colour change Yellow to green: normal (healthy milk). Green to blue: positive (indicative of mastitis and higher pH)

Prevention and control of subclinical mastitis in dairy cattle focus on reducing pathogen exposure, maintaining teat health, and implementing good milking practices to break the infection cycle.

Key Prevention and control Strategies

Milking Hygiene: Use effective post-milking teat dips with germicidal solutions and apply immediately after milking to kill contagious pathogens on teat skin. Use individual cloth towels for drying, wear gloves, and practice proper milking order by milking infected cows last.

Teat Health Maintenance: Keep udders clean and dry, avoid water contact with teats during milking, and maintain healthy teat skin to prevent bacterial entry.

Dry Cow Therapy (DCT): Administer antimicrobial infusions at dry-off to treat existing infections and prevent new ones during the dry period. Internal teat sealants can be used alongside to physically block bacteria.

Environmental Management: Provide clean, dry, inorganic bedding such as sand; regularly clean and replace bedding; control flies and reduce heat stress to decrease environmental pathogen load.

Milking Equipment: Regularly check and maintain milking machine function, especially vacuum and pulsators, and sanitize equipment between uses to prevent pathogen spread.

Vaccination: Some vaccines targeting prevalent pathogens (Staph. aureus, Strep. agalactiae, E. coli) may reduce severity but are not fully protective alone and should complement other control measures.

Herd-Level Control

Routine screening with tests like the California Mastitis Test and somatic cell counting helps identify subclinically infected animals for targeted treatment or segregation to minimize spread.

Economic Impact

Mastitis is responsible for direct and indirect losses. Direct costs include milk production loss, treatment expenses, discarded milk during therapy, and premature culling of animals. Indirect costs arise from reduced reproductive efficiency, prolonged recovery, and increased labor requirements. Annual nationwide economic losses due to mastitis in India are estimated at ₹13,000 crores, with milk yield reduction of 20-30%, accounting for millions of liters lost each year. It is estimated that the cost of subclinical mastitis to the US dairy industry exceeds $1 billion annually (Ott, 1999). In terms of cost breakdown, milk loss accounts for up to 70% of economic losses, treatment (7%), discarded milk (9%), and culling (14%).Yield loss per lactation equal to 300 to 400 kg (4 to 6%) in multiparous cows and 200 to 300 kg in primiparous cows.

Conclusion

Subclinical mastitis remains a major hidden threat to dairy productivity worldwide, especially in developing countries like India, where smallholder and unorganized dairy systems dominate. Although it often goes unnoticed due to the absence of visible symptoms, its impact on milk yield, quality, and farm economics is significant. Early detection through simple diagnostic tools such as the California Mastitis Test (CMT), Somatic Cell Count (SCC), and other biochemical or rapid tests is crucial for effective control. Preventive strategies focused on proper milking hygiene, maintenance of teat health, dry cow therapy, environmental sanitation, and regular equipment maintenance play a vital role in reducing new infections. Long-term control requires herd-level monitoring, farmer awareness, and integration of preventive veterinary practices. By adopting these measures, dairy farmers can substantially improve animal health, milk quality, and profitability while minimizing the economic losses associated with mastitis.

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GIANT AFRICAN SNAIL – A NATURAL RESOURCE FOR FOOD, COSMETICS AND AGRICULTURE

Introduction

The Giant African Snail, *Achatina fulica* (recently renamed as *Lissachatina fulica*), (*Stylommatophora: Achatinidae*) is a highly invasive terrestrial species native to East Africa. This pest has caused widespread damage to Horti and Agricultural ecosystems in India. It is listed among the world's 100 most invasive species by the IUCN (International Union for Conservation of Nature and Natural Resources). In India, its presence has been reported from parts of Assam, North Bihar, Manipur, Nagaland, Meghalaya, Tripura, Odisha and West Bengal. Its invasion, now a serious problem in some of parts of Andhra Pradesh. This invasive pest attack economically important crops such as papaya, guava, chrysanthemum, tomato, okra, cabbage and other vegetables. Due to its polyphagous feeding habit and high reproductive potential, the Giant African Snail (GAS) can rapidly spread and invade new ecosystems, causing severe ecological disruption and threatening native flora and fauna with extinction. Therefore, it is essential to explore alternative management strategies or potential ways to utilize this species for the benefit of humankind.

The Giant African Snail (*Achatina fulica*), though often regarded as an agricultural pest, has several potential uses for human consumption and utilization such as

Mineral and Nutrient Rich Food

Snail meat is highly nutritious and beneficial for human health. It contains balanced levels of essential minerals like calcium, phosphorus, iron and copper, all within safe daily intake limits. Additionally, snail shells can be utilized as mineral supplements in livestock feed, reducing waste and enhancing resource use. (Nkansah et al., 2021)

The protein and amino acid content of GAS meat is comparable to or even higher than, that of conventional protein sources such as pork, chicken, mutton, beef, fish and eggs, as well as novel foods like insects and macroalgae. The shells of *A. fulica* are particularly rich in calcium and can be effectively utilized as a calcium supplement in the diets of laying hens (Pathak et al., 2025)

Safety Considerations

- Wild snails may carry parasites (like *Angiostrongylus cantonensis*, the rat lungworm).
- **Proper cooking (boiling for at least 15–20 minutes)** or farm-rearing under hygienic conditions is essential before consumption.

Medicinal values

A. fulica bioactive compounds show anti-inflammatory, antimicrobial and anticancer effects (mamun et al., 2025). Due to its rich protein and mineral content combined with low fat levels, snail meat can help address nutritional deficiencies and may assist in managing health conditions such as high blood pressure, diabetes mellitus and stroke. Regular consumption of this nutritious meat promotes overall health and wellbeing (Engmann et al., 2013).

In Cosmetics

The snail slime, particularly from *A. fulica*, can help protect the skin from harmful UVA and UVB rays. The extract works by preventing cellular damage and maintaining skin health at the microscopic level. Rich in natural antioxidants and enzymes, snail slime acts as a gentle yet effective photoprotector (Putranti et al., 2022).

Fertilizer

A. fulica can also be used as as Liquid Organic Fertilizer for promoting plant growth (Lestari et al., 2025).

Ornamental and decoration purpose

The shells of the Giant African Snail (GAS) can be creatively used for ornamental and decorative purposes.

They make unique natural pieces for home decor, adding a rustic or coastal charm. Painted or polished, these shells can serve as tabletop accents, wall hangings or showpieces.

Using GAS shells in decoration also promotes sustainable utilization of this invasive species.

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Prakratik Kheti (Natural Farming): A Sustainable Path for Indian Agriculture

Introduction

Prakratik Kheti, or *Natural Farming*, is a holistic and eco-friendly approach to agriculture that works in harmony with nature. It emphasizes cultivating crops without the use of synthetic fertilizers, pesticides, or genetically modified seeds. Instead, it relies on natural resources like cow dung, cow urine, compost, and locally available organic materials to enhance soil fertility and crop productivity.

In recent years, Prakratik Kheti has gained momentum across India as farmers and policymakers recognize the need to reduce chemical dependency, restore soil health, and ensure sustainable livelihoods.

Concept and Philosophy

The philosophy of Prakratik Kheti is rooted in the belief that *nature is self-sustaining*. The soil, water, microorganisms, insects, and plants form a balanced ecosystem that, if undisturbed, can maintain fertility and productivity without external inputs.

The guiding principles include:

1. Do not harm the soil or environment.
2. Promote biodiversity by growing multiple crops together.
3. Use locally available materials for soil nourishment.
4. Reduce cost of cultivation to make farming profitable and sustainable.

This system is not only an agricultural technique but also a way of life — focusing on coexistence with nature rather than exploitation.

Principles of Prakratik Kheti

Natural farming is based on four core principles popularized by Subhash Palekar under the name *Zero Budget Natural Farming (ZBNF)*:

1. **Beejamrit (Seed Treatment):** A mixture of cow dung, cow urine, and lime used to protect seeds from fungal and bacterial infections.

2. Jeevamrit (Soil Microbial Booster): A fermented solution made from cow dung, cow urine, jaggery, pulse flour, and soil. It enhances microbial activity, improving soil fertility and nutrient availability.

3. Mulching: Covering the soil with organic matter such as crop residues, leaves, or dry grass to retain moisture, suppress weeds, and regulate temperature.

4. Waaphasa (Soil Aeration): Maintaining adequate air and moisture balance in the soil to support healthy root growth and microbial activity.

Benefits of Prakratik Kheti

1. **Improved Soil Health:** The use of organic matter enhances soil structure, microbial activity, and nutrient recycling.
2. **Low Cost of Production:** Farmers can reduce dependency on expensive chemical inputs, thus increasing profitability.
3. **Environmental Protection:** Eliminating chemical usage reduces soil and water pollution and promotes biodiversity.
4. **Better Quality Produce:** Natural farming yields are rich in nutrients, taste, and aroma, often fetching higher market value.
5. **Climate Resilience:** Healthy soil with high organic matter content retains more water, helping crops withstand droughts and floods.

Challenges

Despite its many advantages, farmers face some challenges while adopting Prakratik Kheti:

- **Initial yield fluctuations** during the transition phase from chemical to natural methods.
- **Lack of awareness and training** among farmers about proper techniques.
- **Limited market linkages** for organic or naturally grown produce.
- **Policy and institutional support** are still developing in many regions.

Addressing these issues through education, government schemes, and community-based support can make natural farming more accessible and sustainable.

Government Initiatives

The Government of India has introduced several programs to promote natural and organic farming:

Bhartiya Prakritik Krishi Paddhati (BPKP)- Under the *Paramparagat Krishi Vikas Yojana (PKVY)* encourages traditional farming methods. This is a flagship program launched by the **Government of India** to promote natural farming across the country. It is a **sub-scheme** under the larger **Paramparagat Krishi Vikas Yojana (PKVY)**, which encourages farmers to adopt traditional, eco-friendly, and chemical-free agricultural practices.

The main goal of BPKP is to **reduce farmers' dependence on chemical fertilizers and pesticides**, lower the cost of cultivation, and **restore soil health and biodiversity** through natural farming methods.

Objectives of BPKP

1. **Promote chemical-free farming** by using locally available natural resources.
2. **Enhance soil fertility** and maintain ecological balance.

3. **Reduce input costs** and make farming more profitable for small and marginal farmers.
4. **Encourage traditional Indian farming knowledge** and indigenous methods.
5. **Ensure safe and nutritious food production** for consumers.

Key Features

1. **Natural Inputs:** Farmers are trained to prepare and use natural inputs like *Jeevamrit*, *Beejamrit*, *Neemastra*, and *Agniastra* made from cow dung, cow urine, jaggery, and local herbs.
2. **Soil Health Management:** Practices like *mulching*, *crop rotation*, *green manuring*, and *intercropping* help maintain soil fertility and moisture.
3. **Local Cow Importance:** Indigenous (desi) cows are considered vital to the system, as their dung and urine are used to prepare natural fertilizers and pesticides.
4. **Farmer Training and Awareness:** Regular training programs, workshops, and field demonstrations are organized to educate farmers about natural farming techniques.
5. **Cluster-Based Approach:** Farmers are encouraged to form clusters or groups so that natural farming can be practiced collectively for better results and easier marketing.

Implementation

- The scheme is implemented through the **National Mission on Sustainable Agriculture (NMSA)**.
- **Financial assistance** of up to ₹12,200 per hectare is provided for a 3-year period to support input preparation, training, and certification.
- **State governments and agricultural universities** collaborate to promote awareness, provide technical support, and monitor progress.

Benefits of BPKP

1. **Improves soil structure and fertility** naturally.
2. **Reduces environmental pollution** caused by chemical inputs.
3. **Promotes biodiversity** by encouraging the presence of beneficial insects and microorganisms.
4. **Reduces cultivation cost**, increasing farmers' income.
5. **Provides healthier, chemical-free produce** for consumers.
6. **Increases resilience to climate change** by improving water retention and soil health.

Current Status

- BPKP is being implemented in several states, including **Andhra Pradesh, Himachal Pradesh, Gujarat, Madhya Pradesh, and Uttar Pradesh**.
- Thousands of farmers have adopted natural farming under this scheme, demonstrating positive results in yield quality and cost savings.

Zero Budget Natural Farming (ZBNF) - Zero Budget Natural Farming (ZBNF) is an innovative farming method developed and popularized by **Subhash Palekar**, a renowned agricultural scientist from Maharashtra, India. The term "zero budget" means that the cost of cultivation is **almost zero**, as farmers use **natural**

inputs available on their farms instead of buying expensive chemical fertilizers, pesticides, or seeds.

ZBNF is a type of **Prakratik Kheti (Natural Farming)** that focuses on **working with nature**, reducing external dependency, and ensuring sustainable livelihoods for farmers. It has been widely adopted in states like **Andhra Pradesh, Karnataka, Maharashtra, Himachal Pradesh, and Gujarat**.

Objectives of ZBNF

1. To **eliminate chemical inputs** in agriculture.
2. To **reduce the cost of cultivation** and free farmers from debt.
3. To **protect soil fertility, water, and biodiversity**.
4. To **empower farmers** with knowledge and self-reliant practices.
5. To **produce healthy, chemical-free food** for consumers.

Core Principles of ZBNF

ZBNF is based on **four key principles** developed by Subhash Palekar:

1. **Beejamrit (Seed Treatment):**
   A mixture of **cow dung, cow urine, lime, and soil** is used to coat seeds before sowing.
   It protects the seeds from fungal and bacterial infections and improves germination.
2. **Jeevamrit (Microbial Inoculant):**
   A fermented solution made from **cow dung, cow urine, jaggery, pulse flour, and local soil**.
   It acts as a tonic for the soil, enriching it with beneficial microorganisms that make nutrients available to plants.
3. **Mulching:**
   Covering the soil with crop residues, dry leaves, or grasses.
   It helps retain soil moisture, prevent weed growth, and maintain soil temperature.
4. **Waaphasa (Soil Aeration):**
   Maintaining a proper balance of air and moisture in the soil.
   It ensures healthy root growth and prevents soil compaction.

Supporting Practices

- **Agniastra, Brahmastra, and Neemastra:**
  Natural pest repellents made from cow urine, cow dung, neem leaves, chili, garlic, and local herbs.
- **Intercropping and Mixed Cropping:** Growing multiple crops together to enhance biodiversity and reduce risk.
- **Use of Local Seeds:** Emphasizing indigenous, drought-resistant, and pest-tolerant seed varieties.

Benefits of ZBNF

1. **Eco-friendly:** Protects soil health, water bodies, and beneficial organisms.
2. **Low-cost farming:** Farmers don't need to buy chemical inputs or hybrid seeds.
3. **Improved soil fertility:** Natural inputs increase organic matter and microbial life.
4. **Better crop quality:** Produce is free from harmful chemicals and richer in nutrients.
5. **Resilient farming:** ZBNF crops withstand droughts, floods, and other climate challenges better than chemical farming.

6. **Farmer empowerment:** Encourages self-reliance and reduces dependence on external agencies.

Challenges in Implementation

- Initial yield reduction during the transition from chemical to natural methods.
- Limited awareness and training among farmers.
- Difficulty in obtaining natural inputs in urban or non-cattle-owning areas.
- Need for stronger marketing and certification systems for natural produce.

Government Support and Expansion

- The **Government of India** and several state governments have recognized ZBNF as a sustainable alternative to chemical farming.
- **Andhra Pradesh** has launched the ambitious **Andhra Pradesh Community-managed Natural Farming (APCNF)** program to scale ZBNF across the state.
- The **NITI Aayog** and **Indian Council of Agricultural Research (ICAR)** have also conducted studies and pilot projects to evaluate its effectiveness.

Conclusion

Zero Budget Natural Farming (ZBNF) is a revolutionary movement that revives traditional Indian wisdom while addressing modern agricultural challenges. It provides a sustainable, low-cost, and eco-friendly alternative to chemical-based farming systems.

By reducing input costs, protecting the environment, and improving the quality of food, ZBNF offers a **path toward self-reliant and resilient agriculture**, ensuring both **economic security for farmers** and **ecological balance for the planet**.

Conclusion

Prakratik Kheti represents a return to our roots — an agricultural system that respects natural processes while ensuring food security and ecological balance. In a world facing climate change, soil degradation, and food quality concerns, natural farming offers a sustainable and cost-effective solution. By embracing Prakratik Kheti, farmers can protect their land, improve their livelihoods, and contribute to a healthier planet for future generations.

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MILLETS: THE CLIMATE-SMART SUPERFOOD OF THE FUTURE

Introduction

For centuries, millets have been a staple food across Asia and Africa, sustaining civilizations in some of the harshest farming environments. Yet, with the Green Revolution and the focus on rice and wheat, millets lost their prime status and were unfairly tagged as "coarse grains." Today, in the face of climate change, malnutrition, and the search for sustainable agriculture, millets are making a comeback as the **climate-smart superfood of the future**.

The **United Nations General Assembly declared 2023 as the International Year of Millets (IYoM 2023)**, recognizing their immense potential to address global food security, nutrition, and environmental sustainability. This global acknowledgment has opened doors for research, policies, and consumer awareness about these forgotten grains.

What are Millets?

Millets are a group of small-seeded, hardy cereal grains that have been cultivated for thousands of years. Naturally rich in nutrients, gluten-free, and highly resilient to drought and poor soils, millets are emerging as a key solution for food and nutritional security. They are broadly classified as:

Category	Common Name	Local/Popular Name	Scientific Name
Major Millets	Pearl millet	Bajra	*Pennisetum glaucum*
	Finger millet	Ragi	*Eleusine coracana*
	Foxtail millet	Kangni/Korra	*Setaria italica*
Minor Millets	Little millet	Kutki/Samai	*Panicum sumatrense*
	Kodo millet	Kodo	*Paspalum scrobiculatum*
	Proso millet	Cheena/Barri	*Panicum miliaceum*
	Barnyard millet	Sanwa/Jhangora	*Echinochloa frumentacea*
	Brown top millet	Korale	*Brachiaria ramosa*

Unlike rice and wheat, millets are highly resilient crops requiring **less water, fewer inputs, and minimal care**, making them ideal for resource-poor farmers.

Climate-Smart Qualities of Millets

Water efficiency: Millets need **70–80% less water** compared to rice. Pearl millet, for instance, can grow with annual rainfall as low as 200–250 mm, making it highly suitable for drought-prone regions.

Heat tolerance: Rising global temperatures threaten food production. Millets, however, thrive in high temperatures, some even growing well beyond 40°C.

Low carbon footprint: Millet cultivation demands minimal chemical fertilizers and pesticides. Their hardy nature reduces dependency on external inputs, leading to lower greenhouse gas emissions.

Soil health restoration: Millets improve soil structure and biodiversity. Their short duration (60–90 days) allows them to fit into multiple cropping systems, enhancing farm resilience.

In short, millets are the perfect "climate-resilient crops" to safeguard food production under unpredictable weather patterns.

Millets – Nature's Nutritional Powerhouse

Millets are rightly called **Nutri-cereals** because of their impressive nutritional profile:

High in fiber: Supports digestion, lowers cholesterol, and helps maintain healthy weight.

Rich in micronutrients: Finger millet has 10 times more calcium than rice, foxtail millet is rich

in iron, barnyard millet provides phosphorus, and pearl millet is packed with iron and zinc to support blood health and immunity.

- **Low glycaemic index:** Helps control blood sugar and manage diabetes.
- **Gluten-free:** Safe for people with celiac disease or gluten intolerance.
- **Protein source:** Proso millet and pearl millet provide quality protein, ideal for vegetarian diets.

By providing essential nutrients and supporting health, millets address both malnutrition and lifestyle diseases such as diabetes and cardiovascular issues.

India's Role in Millets Revival

India is the largest producer of millets, contributing nearly 20% of global production and 80% of Asia's output. The top millet-growing states include Rajasthan, Maharashtra, Karnataka, Andhra Pradesh, Telangana, and Madhya Pradesh. Additionally, Gujarat is specifically important for summer-season pearl millet cultivation.

Government Initiatives:

- **2023 as International Year of Millets** was spearheaded by India's proposal at the UN.
- **Inclusion in Public Distribution System (PDS)** and **mid-day meals** to improve nutritional intake of vulnerable groups.
- **Millet Mission programs** in several states (e.g., Odisha, Chhattisgarh) encouraging farmers to shift towards millet-based farming.
- **Start-up support** for millet-based food products and value chains.

These initiatives are not just supporting farmers but also building consumer demand for millet-based products.

From "Poor Man's Food" to "Smart Food"

In earlier decades, millets were largely consumed by rural households and associated with poverty. However, modern research and growing health awareness have rebranded them as **"Smart Food"** food that is:

- Good for **you** (nutrition and health)
- Good for the **planet** (sustainability)
- Good for the **farmer** (resilient crops and better income)

This transformation is reflected in growing markets for **millet-based noodles, pasta, cookies, breakfast cereals, and energy bars**. Urban consumers are embracing millets as part of a healthy lifestyle, while global markets are opening up to millet-based products.

Challenges in Millet Promotion

Despite their advantages, millets still face hurdles:

- **Consumer preference** for rice and wheat due to taste and cooking habits.
- **Lack of processing technologies** compared to well-developed rice/wheat industries.
- **Policy bias** towards rice and wheat with MSP (Minimum Support Price) and procurement advantages.
- **Awareness gap** among urban consumers about cooking methods and health benefits.

Addressing these challenges requires policy support, investment in millet value chains, and targeted awareness campaigns.

Future Prospects

Millets align perfectly with the **Sustainable Development Goals (SDGs)** from ending hunger to combating climate change. To strengthen their role, the following steps are essential:

- **Policy Support**: Expanding MSP, procurement, and PDS inclusion.
- **Research and Development**: Breeding climate-resilient, high-yielding millet varieties.
- **Value Chain Development**: Investment in processing units, branding, and packaging.

- **Consumer Awareness**: Nutrition campaigns, millet food festivals, and inclusion in modern diets.
- **Export Opportunities**: Leveraging global demand for gluten-free and organic products.

Conclusion

Millets are not just another set of crops they are **a solution to multiple global challenges**. They provide nutrition security, strengthen farmer resilience, restore soil and ecosystems, and reduce our carbon footprint. With the right policies, awareness, and consumer acceptance, millets can truly become the **climate-smart superfood of the future**. By reviving millets, we are not only reconnecting with our rich agricultural heritage but also paving the way for a **healthier, more sustainable planet**. It's time we bring millets back to our plates for ourselves, for the farmers, and for the Earth

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Scientific Cultivation of Wheat Seed Production

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important staple food crops worldwide, providing a major source of calories and protein for a large portion of the global population. It holds a crucial place in the agricultural economy and food security strategies of many countries. To meet the increasing demand for wheat due to population growth, urbanization, and changing dietary patterns, it is essential to improve wheat productivity. One of the fundamental factors influencing wheat productivity is the quality of seed used in cultivation. Scientific cultivation of wheat seed production is a critical component in ensuring the availability of high-quality seeds that have superior germination rates, genetic purity, and resistance to diseases and pests. The seed is the starting point of the crop cycle, and the use of scientifically produced seed can lead to higher yields, better adaptability to environmental stresses, and improved profitability for farmers.

Importance of Seed in Wheat Cultivation

Seeds play a pivotal role in the wheat production system. The quality of seed determines the initial stand establishment, growth vigor, and eventual yield potential of the crop. The use of good-quality seeds results in:

- **Improved germination and emergence**: High-quality seeds have high viability, leading to uniform and rapid germination.
- **Enhanced yield potential**: Seeds produced under scientific protocols maintain genetic purity and vigor, which translates into higher grain yields.
- **Resistance to diseases and pests**: Certified seeds often come from disease-free plants and are sometimes treated to prevent seed-borne infections.
- **Adaptability to environmental conditions**: Seeds from improved varieties can be selected based on adaptability to specific climatic and soil conditions.
- **Economical advantages**: Although the cost of certified seeds may be higher, the increased yield and reduced losses justify the investment.

Seed Production vs. Grain Production:

- **Grain production** focuses on maximizing the total quantity of grain harvested for consumption.
- **Seed production** focuses on producing seeds with high genetic purity, germination rate, and vigor for the next planting season.

Objectives of Scientific Wheat Seed Production

- Production of genetically pure and true-to-type seed.
- Ensuring high germination and vigor.
- Minimizing contamination by other crop varieties, weed seeds, and pathogens.
- Producing seeds that are free from seed-borne diseases and pests.
- Meeting seed certification standards for quality assurance.
- Supporting sustainable agriculture by providing quality planting material.

Climate, Soil, and Field Preparation

Climatic Requirements for Wheat Seed Production

- **Temperature:**
  Wheat requires a temperature range of 12°C to 25°C for optimal growth. Temperatures between 15°C and 20°C during the grain-filling stage are ideal for producing high-quality seeds. Excessive heat during this period can cause poor grain filling, leading to shriveled seeds and lower seed vigor. Conversely, temperatures below 10°C may delay germination and slow crop development.
- **Rainfall:**
  Wheat generally requires moderate rainfall ranging between 300 mm to 900 mm during its growth period. For seed production, well-distributed rainfall or irrigation is preferred to avoid drought stress and to maintain soil moisture at optimum levels. Excessive rainfall, especially near maturity, can cause diseases like rust and ergot, which degrade seed quality.
- **Sunlight:**
  Adequate sunlight is necessary for photosynthesis and energy accumulation in seeds. Cloudy or low-light conditions can reduce seed weight and vigor.
- **Humidity:**
  Moderate relative humidity (50-60%) favors healthy seed development. High humidity, particularly during the maturation and harvesting stages, increases the risk of fungal infections and seed deterioration.

Soil Requirements for Wheat Seed Production

Soil conditions greatly influence the growth and development of wheat plants and subsequently the quality of seeds produced.

- **Soil Type:** Wheat grows well on loamy, well-drained soils rich in organic matter. The best soils for seed production are those that retain moisture but do not become waterlogged. Sandy loams and silty loams with good tilth and drainage are ideal.
- **Soil pH:** Wheat prefers a soil pH between 6.0 and 7.5. Soils that are too acidic (<5.5) or alkaline (>8.0) can limit nutrient availability and hinder seed development.
- **Soil Fertility:** Fertile soils with adequate levels of nitrogen (N), phosphorus (P), and potassium (K) are essential.

Micronutrients like zinc (Zn), manganese (Mn), and copper (Cu) also play important roles in seed quality.

- **Soil Health:** The presence of beneficial soil microorganisms promotes nutrient uptake and reduces disease incidence. Crop rotation and organic amendments help maintain soil health.

Site Selection and Isolation Distance

For scientific seed production, careful site selection and isolation are critical to maintain genetic purity and prevent contamination from other wheat varieties or related species.

- **Site Selection:** Choose sites with uniform topography, good drainage, and minimal risk of waterlogging or frost. Avoid locations prone to high weed infestation or diseases.
- **Isolation Distance:** Wheat is primarily self-pollinated but can have up to 1-5% cross-pollination due to wind and insects. To maintain genetic purity, an isolation distance of 200-400 meters (depending on the seed class and certification guidelines) from other wheat varieties or off-type plants is recommended.

Field Preparation for Wheat Seed Production

Proper field preparation ensures an ideal seedbed for uniform seed germination and healthy crop growth.

- **Land Clearing:** Remove previous crop residues, weeds, and debris. Deep plowing followed by multiple harrowings creates a fine tilth.
- **Tillage:** Conventional tillage involving plowing, followed by harrowing and leveling, helps in breaking clods and creating a smooth seedbed.
- **Soil Testing and Amendments:** Conduct soil testing to determine nutrient status and pH. Apply lime if soil is acidic and balance fertilizers according to test results.
- **Fertilizer Application:** Incorporate base fertilizers before sowing. Nitrogen can be applied in splits, with part at sowing and the rest during the crop growth stages.
- **Field Layout:** Plan the field layout to facilitate proper irrigation, drainage, and pest management.

Importance of Seedbed Preparation

- Uniform seed placement at the correct depth.
- Better seed-to-soil contact, enhancing germination.
- Adequate moisture retention.
- Effective root penetration and nutrient absorption.
- Easier weed control and pest management.

Varietal Selection, Sowing Techniques, and Crop Management

Varietal Selection for Wheat Seed Production

Selecting the appropriate wheat variety is one of the most critical decisions in seed production. The chosen variety should align with the agro-climatic conditions, market demands, and farmer preferences.

- **Genetic Purity and True-to-Type:** Only genetically pure and true-to-type varieties recommended by seed certification agencies or agricultural research institutions should be used for seed production. This ensures uniformity and expected performance in the next generation.

- **Adaptability:** Varieties should be selected based on their adaptability to local climatic conditions such as temperature, rainfall, and day length.
- **Disease and Pest Resistance:** Resistant varieties reduce losses due to biotic stresses and lower the need for chemical controls, thus producing healthier seeds.
- **Yield Potential and Quality:** High-yielding varieties with superior grain quality and good milling and baking characteristics are preferred to meet consumer demands.
- **Maturity Period:** Varieties with appropriate maturity periods that fit into the cropping calendar help in timely harvesting, preventing seed deterioration.
- **Seed Certification Status:** Use breeder or foundation seed as the source for seed production to ensure the highest genetic quality.

Seed Rate and Seed Treatment

- **Seed Rate:** The seed rate varies depending on the variety, sowing method, and seed size. For wheat seed production, seed rates typically range from 80 to 120 kg per hectare to achieve the desired plant population.
- **Seed Treatment:** Treating seed with fungicides and insecticides before sowing protects against soil-borne and seed-borne pathogens and pests. Common treatments include:
    - **Fungicides** (e.g., thiram, carbendazim) to control fungal diseases.
    - **Insecticides** (e.g., imidacloprid) to protect from early pests.
    - Use of bio-agents like *Trichoderma* spp. can promote seed health naturally.

Sowing Techniques for Wheat Seed Production

Accurate and timely sowing is vital for uniform crop establishment and healthy seed development.

- **Time of Sowing:** The optimum sowing time varies regionally but generally falls between mid-November and early December in temperate zones and October-November in subtropical zones. Early sowing can lead to early maturity and escape from terminal heat stress, whereas late sowing often reduces yield and seed quality.
- **Sowing Methods:** Various sowing techniques include:
    - **Broadcasting:** Traditional but less efficient, leading to uneven plant distribution.
    - **Drilling:** Recommended method for seed production; seeds are placed at uniform depth and spacing using seed drills.
    - **Line Sowing:** Provides better plant population control and ease of intercultural operations.
- **Sowing Depth:** Seeds should be sown at a depth of 3-5 cm depending on soil moisture conditions. Too shallow sowing causes poor germination and weak

seedlings; too deep sowing delays emergence.

- **Row Spacing:** Maintain row spacing of 20-25 cm to facilitate proper aeration, sunlight penetration, and management practices.

Crop Management Practices

Proper crop management is essential to ensure the production of high-quality seeds with maximum vigor.

Nutrient Management

- Balanced fertilization based on soil test results is critical.
- Nitrogen is particularly important for vegetative growth and seed development but must be carefully managed to avoid lodging.
- Phosphorus promotes root development and early growth.
- Potassium enhances overall plant health and stress tolerance.
- Application of micronutrients like zinc improves seed quality and germination.

Irrigation Management

- Wheat requires adequate moisture, especially during tillering, flowering, and grain-filling stages.
- Avoid water stress during these critical phases to prevent yield loss and poor seed quality.
- Over-irrigation should be avoided to prevent diseases and lodging.

Weed Management

- Weeds compete with wheat for nutrients, water, and light, reducing seed yield and quality.
- Employ integrated weed management, including pre- and post-emergence herbicides, mechanical weeding, and crop rotations.
- Ensure weed-free seed production fields to prevent contamination.

Disease and Pest Management

- Regular monitoring and timely control measures prevent damage to the seed crop.
- Use resistant varieties, seed treatment, and foliar sprays as needed.
- Maintain field sanitation and crop rotation to reduce disease buildup.

Rouging

- Remove off-type plants, diseased, and weak plants to maintain genetic purity.
- Rouging is especially important during seed production to prevent contamination.

Crop Monitoring and Record Keeping

- Frequent field inspections for growth, pest/disease incidence, and plant uniformity.
- Maintain detailed records of field activities, inputs, and observations to ensure traceability and certification compliance.

Disease and Pest Management, and Nutrient Management

Disease Management in Wheat Seed Production

Wheat crops are susceptible to a variety of diseases that can severely affect seed quality, yield, and genetic purity. Effective disease management is crucial in scientific seed production.

Common Diseases Affecting Wheat Seeds

- **Rusts (Leaf Rust, Stem Rust, Stripe Rust):** Caused by *Puccinia* spp., rusts are fungal diseases that reduce photosynthetic area and cause premature leaf senescence. Infected plants produce shriveled seeds with poor germination.
- **Powdery Mildew:** Caused by *Blumeria graminis*, it forms white powdery growth on leaves, reducing plant vigor and seed quality.
- **Fusarium Head Blight (Scab):** This fungal disease causes bleaching of the wheat heads and produces mycotoxins harmful to humans and animals. Infected seeds have poor germination and are often discarded during certification.
- **Ergot:** Caused by *Claviceps purpurea*, ergot replaces wheat grains with dark sclerotia that are toxic and reduce seed quality.
- **Bunt and Smut Diseases:** These seed-borne fungal diseases replace grain with spores, severely lowering seed purity and vigor.
- **Seedling Blight and Root Rot:** Affect seedlings and young plants, causing poor stand establishment.

Disease Management Practices

- **Use of Disease-Resistant Varieties:** Select varieties bred for resistance to major diseases prevalent in the region.
- **Seed Treatment:** Treat seeds with fungicides like carbendazim or thiram to control seed-borne diseases.
- **Field Sanitation:** Remove crop residues and volunteer plants that may harbor pathogens.
- **Crop Rotation:** Avoid planting wheat continuously on the same field to break the disease cycle.
- **Fungicide Application:** Apply foliar fungicides at critical growth stages to control foliar diseases.
- **Monitoring and Early Detection:** Regular scouting helps detect early signs of disease and allows timely intervention.

Pest Management in Wheat Seed Production

Common Pests Affecting Wheat Seeds

- **Aphids:** Sap-sucking insects that weaken plants and transmit viral diseases.
- **Hessian Fly:** Larvae feed on the stem base, stunting plant growth.
- **Wheat Stem Sawfly:** Larvae bore into stems causing lodging.
- **Armyworms and Cutworms:** Feed on leaves and seedlings, causing defoliation.
- **Grain Weevils and Other Storage Pests:** Attack harvested seeds during storage, causing quality loss.

Pest Management Strategies

- **Use of Resistant Varieties:** Select varieties with tolerance or resistance to key pests.

- **Biological Control:** Promote natural enemies such as lady beetles, parasitic wasps, and predatory mites.
- **Cultural Practices:** Timely sowing, crop rotation, and field sanitation reduce pest incidence.
- **Chemical Control:** Use insecticides judiciously following integrated pest management (IPM) principles to minimize resistance buildup.
- **Seed Treatment:** Use insecticidal seed treatments to protect seedlings.
- **Proper Storage:** Maintain clean, dry storage conditions and use appropriate insecticides or fumigants to prevent post-harvest pest damage.

Nutrient Management in Wheat Seed Production

Macronutrients

- **Nitrogen (N):** Critical for vegetative growth and grain filling. Excessive nitrogen can lead to lodging and delayed maturity. Split application is recommended — part at sowing and the rest during tillering and booting stages.
- **Phosphorus (P):** Enhances root development and early seedling vigor, which is vital for uniform crop establishment.
- **Potassium (K):** Important for stress resistance, grain quality, and seed filling.

Micronutrients

- **Zinc (Zn):** Deficiency leads to poor seed development and low germination rates.
- **Sulfur (S):** Important for protein synthesis and enzyme function.
- **Boron (B), Manganese (Mn), Copper (Cu):** Deficiencies can reduce seed set and grain quality.

Fertilizer Recommendations

- Conduct soil tests to tailor fertilizer application.
- Apply fertilizers based on crop growth stages.
- Use organic amendments like farmyard manure and compost to improve soil health and nutrient availability.
- Foliar sprays of micronutrients can correct deficiencies during crop growth.

Integrated Disease and Pest Management (IDPM)

An integrated approach combining cultural, biological, chemical, and genetic methods optimizes disease and pest control while minimizing environmental impact.

- Regular field monitoring.
- Use resistant varieties.
- Timely seed treatment and foliar sprays.
- Biological control agents.
- Proper crop rotation and field sanitation.
- Judicious use of pesticides with attention to resistance management.

Harvesting, Processing, Quality Testing, and Seed Certification

Harvesting of Wheat Seed Crop

- **Harvest Timing:** Wheat seeds reach physiological maturity when grain moisture is around 30-35%. Harvesting should ideally be done when seed moisture is between 12-14% to minimize mechanical damage and avoid losses due to shattering or lodging.

- **Signs of Maturity:** The wheat plant turns golden-yellow, and grains become hard. The moisture content can be measured using moisture meters.
- **Harvesting Methods:**
    - **Manual Harvesting:** Involves cutting the crop with sickles; careful handling reduces seed damage.
    - **Mechanical Harvesting:** Using combine harvesters is efficient but requires skilled operation to minimize seed damage.
- **Harvest Precautions:** Avoid harvesting under wet conditions to prevent seed clumping and fungal infections. Minimize mechanical damage that reduces seed viability.

Post-Harvest Processing of Wheat Seed

Proper post-harvest handling preserves seed quality and prepares seeds for certification and sale.

- **Threshing:** Separate grains from the chaff carefully to avoid seed damage. Use machines adjusted for seed size and hardness.
- **Cleaning:** Remove foreign matter such as dust, weed seeds, and broken seeds using sieves, gravity separators, and air blowers. Clean seeds reduce contamination and improve germination.
- **Drying:** Dry seeds to safe moisture levels (below 12%) to prevent fungal growth and storage losses. Use sun drying or mechanical dryers.
- **Grading:** Grade seeds based on size and weight to ensure uniformity, which promotes even germination.
- **Seed Treatment:** Treat seeds with fungicides and insecticides to protect against seed-borne diseases and storage pests.
- **Packaging and Storage:** Use moisture-proof, insect-proof bags or containers. Store seeds in cool, dry, and well-ventilated areas to maintain viability.

Seed Quality Testing

- **Physical Purity:** Percentage of pure seed in the sample, excluding inert matter and other seeds.
- **Germination Percentage:** Proportion of seeds that successfully germinate under standard conditions, usually above 85% for certified seeds.
- **Seed Moisture Content:** Ideally below 12% to ensure longevity in storage.
- **Seed Health:** Free from seed-borne diseases and pests, verified by laboratory testing.
- **Seed Vigor:** Ability of seeds to germinate rapidly and uniformly under a range of environmental conditions.
- **Genetic Purity:** Assessed through field inspections for off-types and, if available, molecular markers.

Seed Certification Process

Certification ensures that the seeds meet prescribed standards of quality and purity.

Classes of Seed: Breeder Seed: Produced by plant breeders, highest genetic purity.

   - **Foundation Seed:** Produced from breeder seed under strict supervision.
   - **Certified Seed:** Produced from foundation seed and made available to farmers.
- **Field Inspection:** Regular field inspections during the growing period ensure adherence to isolation, rouging, and crop management protocols.
- **Seed Sampling and Testing:** Post-harvest samples are sent to official seed testing laboratories for quality analysis.
- **Tagging and Labeling:** Certified seeds carry official tags and labels with details of variety, class, germination percentage, purity, and lot number.
- **Maintaining Traceability:** Documentation and record-keeping from breeder to certified seed maintain traceability and accountability.

Importance of Seed Certification

- Ensures availability of genetically pure and high-quality seeds.
- Builds farmer confidence in seed performance.
- Facilitates market acceptance and higher prices.
- Supports national food security by improving crop productivity.
- Encourages adherence to scientific seed production protocols.

Economics and Conclusion

Economics of Scientific Wheat Seed Production

Understanding the economics behind wheat seed production helps farmers and stakeholders make informed decisions and ensures the sustainability of seed enterprises.

Cost of Production

- **Land Preparation:** Includes plowing, harrowing, leveling, and seedbed preparation.
- **Seed Costs:** Purchase of breeder or foundation seed is often expensive but crucial for genetic purity.
- **Fertilizers and Amendments:** Fertilizers for balanced nutrition and soil amendments based on soil tests.
- **Plant Protection:** Costs of fungicides, insecticides, and seed treatment chemicals.
- **Labor:** For sowing, rouging, irrigation, weeding, and harvesting.
- **Machinery and Equipment:** For sowing, harvesting, threshing, cleaning, drying, and packaging.
- **Certification and Inspection Fees:** Charges for seed certification services.

Returns and Profitability

- Certified wheat seed commands premium prices in the market due to its superior quality and guaranteed performance.
- Higher germination rates and better crop stands lead to increased yield for farmers using certified seeds.
- Disease-free and genetically pure seeds reduce crop failures and increase profitability.
- The investment in quality seed production is justified by the enhanced productivity and farmer satisfaction.

Market Demand and Supply

- Demand for certified wheat seed is growing due to increased awareness and government policies promoting quality seed use.
- Seed producers must ensure timely production, processing, and distribution to meet planting season requirements.
- Government subsidies, seed fairs, and extension services support seed producers and farmers.

Challenges in Wheat Seed Production

- Maintaining genetic purity in cross-pollinated or mixed cropping areas.
- Managing pests and diseases that can reduce seed quality.
- Ensuring timely availability of breeder and foundation seeds.
- Infrastructure and technology gaps in seed processing and storage.
- Awareness and acceptance of certified seeds among smallholder farmers.
- Climate change impacts affecting crop performance and seed viability.

Future Perspectives

- Use of biotechnology and molecular markers to enhance seed purity and accelerate breeding.
- Precision agriculture techniques for monitoring crop health and optimizing inputs.
- Development of climate-resilient wheat varieties for sustainable seed production.
- Strengthening seed certification and quality assurance systems.
- Farmer education and capacity building on scientific seed production and handling.

Conclusion: Scientific cultivation of wheat seed production is a cornerstone for sustainable agriculture and food security. By adopting best practices—from varietal selection, site preparation, crop management, pest and disease control, to post-harvest processing and certification—seed producers can ensure the availability of high-quality seeds that boost productivity and profitability.

Investing in quality seed production not only benefits individual farmers but also strengthens national economies and supports global efforts to feed a growing population. Continued research, innovation, and extension support are vital to overcoming challenges and enhancing the efficiency of wheat seed production systems.

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Recent Trends in Innovative Approaches in Scientific and Sustainable Forest Management, Soil Health, Land Resources and Land Use Planning and Management

Abstract

Forests, soil, and land are crucial for life, but increasing urbanization, agriculture, and climate change have placed these resources under severe stress. This essay explores recent innovative and scientific approaches in sustainable forest management, soil health maintenance, land resource utilization, and land use planning. It highlights the use of modern technologies like GIS, drones, IoT, and AI, as well as community-led efforts such as Joint Forest Management. The integration of climate action and Sustainable Development Goals (SDGs) further strengthens these practices. Through real-world examples from India and abroad, this essay emphasizes the importance of smart, inclusive and collaborative approaches for long-term sustainability.

Keywords: Forest management, soil health, GIS, remote sensing, precision agriculture, land use planning, climate change, sustainable development, agroforestry, carbon sequestration.

Introduction:

Forests, soil, and land are very important for life. But due to growing cities, farming, and climate change, they are under pressure.

Figure 1: Forest cover change in protected areas, showcasing correlation with management effectiveness scores [13].

We now need better and smarter ways to manage these resources. This essay explores the recent trends and innovative methods in scientific and sustainable forest management, soil health improvement, land resource optimization, and strategic land use planning. It also highlights the integration of these efforts with climate goals and sustainable development targets.

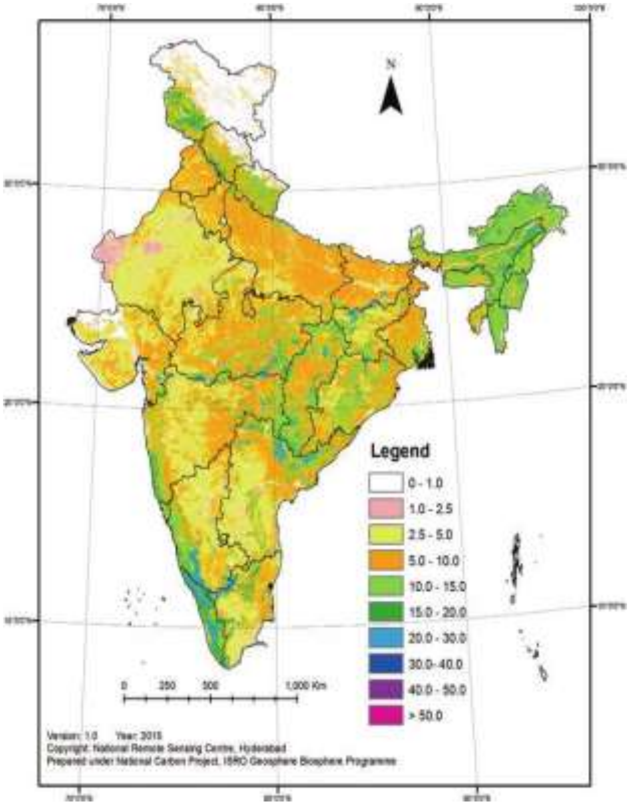

Figure 2: Spatial distribution of soil organic carbon across India (NRSC, 2015) [14].

1.Scientific and Sustainable Forest Management:

Forests play a crucial role in maintaining ecological stability by purifying air, conserving water, and supporting biodiversity. Modern management approaches increasingly rely on advanced monitoring tools such as satellite-based remote sensing, drone surveillance, and GIS mapping to assess forest cover, detect illegal logging, and identify degradation hotspots.

GIS and Remote Sensing in Forest Monitoring: Satellite imagery [2], combined with GIS platforms, enables precise tracking of forest dynamics. For example, the Forest Survey of India (FSI) [1] publishes biennial forest cover reports using data from Google Earth Engine and MODIS/Landsat sensors.

Drone Technology in Forest Surveillance: Drones provide high-resolution imagery for detecting forest health issues, mapping fire-prone areas, and monitoring encroachments. In Uttarakhand, the Forest Department employs drones for patrolling sensitive forest zone [3].

Forest Certification and Sustainable Logging: Certification schemes such as the Forest Stewardship Council (FSC) ensure that timber harvesting complies with environmental and social standards [4].

2. Soil Health

Healthy soil is the starting point for productive farms and resilient ecosystems. Building and maintaining it is not just about one solution—it involves a mix of approaches that work together: adding organic matter to enrich fertility, growing a variety of crops to break pest cycles, and using precision tools to ensure every drop of water or gram of fertilizer serves its purpose.

Precision Agriculture: In recent years, farmers have had access to tools that were once unthinkable in rural fields—GPS-guided tractors, IoT-based soil sensors, and AI-powered advice platforms. These innovations allow farmers to give crops exactly what they need, when they need it, without wasting resources [5]. In India, for example, the Soil Health Card Scheme—launched in 2015—has reached millions, handing them easy-to-understand reports on their soil's nutrient status. Many farmers now speak of using these cards as a regular guide for what to plant and how to feed it.

Soil Carbon Sequestration: While technology works above ground, there's equally important work happening underfoot. Simple but powerful practices—like leaving crop residues on the surface, planting cover crops in the off-season, or integrating trees into farmland—help the soil capture carbon from the atmosphere and hold it for the long term. Promoted under initiatives like **4 per 1000**, which aims to increase global soil carbon stocks. (conservation). This peer-reviewed study from ICAR-IARI, New Delhi, shows that **zero tillage with residue retention** increased soil organic carbon (SOC) by ~32% in the top 30 cm layer, sequestering ~0.76 Mg C/ha/yr compared to conventional tillage [6].

3. Land Resource Management

Efficient land resource management is essential for preventing degradation and ensuring sustainable use. Geospatial technologies, watershed management, and land restoration initiatives are central to this effort [1]. Programs such as Gujarat's Sujalam Sufalam employ desilting and rainwater harvesting to restore productivity. The Bhuvan portal by ISRO is an important tool for monitoring land and water resources.

Figure 4: Screenshot from ISRO Bhuvan platform demonstrating geospatial monitoring of land and resources [15].

4. Land Use Planning:

Before using land for buildings or farms, we must plan carefully. Land should be used based on its type, like hilly, wet, or dry. Eco-sensitive zones protect forests and rivers; mapping around wildlife sanctuaries and national parks. Digital land records help in stopping illegal land use. Programs like Digital India Land Records Modernization Programme are improving land ownership transparency and planning [7].

5. Link with Climate and SDGs:

Protecting land and forests helps fight climate change. It also supports goals like zero hunger and saving nature. India is working to grow more forests to trap carbon and fight global warming. Forests and land health contribute to SDGs: 13 (climate action), 15 (Life on land) and 2 (Zero hunger). Example: **India's NDC** under the Paris Agreement includes increasing forest cover as a carbon sink [8].

6. Technology and Research:

New tools like AI, sensors, and even blockchain help manage forests and land in a smart way [9]. They give accurate data for decision making and also help predict deforestation risks, soil erosion, and crop productivity.

7. Case Studies:

1. Forest Restoration in Telangana: Through the Haritha Haram program, over 2.2 billion saplings were planted, increasing green cover [10].
2. Sustainable Land Use in Sikkim: Became India's first fully organic state by adopting holistic soil and land management practices [11].
3. Reforestation in Ethiopia (Green Legacy Initiative): Over 4 billion trees planted in 2019 to combat desertification [14].

8. Challenges and Solutions

There are problems like lack of money, old systems and poor law follow-up. We need better plans, tech use and people's involvement for success.

CHALLENGES:

-Climate Change Effects

- Irregular rainfall, floods, droughts, and wildfires damage forests and soil.
- Increases uncertainty in land use planning.

-Fragmented Land Ownership

- Small and scattered land holdings make large-scale planning difficult, especially in rural India.

-Lack of Coordination Between Departments

- Forest, agriculture, and revenue departments often work in silos, causing delays.

-Low Awareness Among Farmers

- Many farmers are unaware of sustainable practices or schemes like Soil Health Cards.

-Slow Adoption of New Technologies

- Limited funds, training, or internet access in rural areas restrict modern tech use.

-Limited Local Participation

- Many government schemes are top-down with less community engagement.

SOLUTIONS :

1. Integrated Land Management Policies:
   - All departments should work under a common platform using shared data.
2. Promotion of Agroforestry:
   - Encouraging farmers to grow trees alongside crops boosts income and soil health.
3. Village-Level Resource Maps:
   - Use GIS to create resource maps for each village for better planning and use.
4. Eco-education in Schools and Villages:
   - Start early awareness on forests and soil through local workshops and school programs.
5. Incentives for Organic and Natural Farming:
   - Provide financial support, subsidies, and markets for organic produce.
6. Land Bank and Land Pooling Schemes:
   - Combine small land pieces for coordinated use (already used in urban planning in Gujarat and Maharashtra).
7. Faster and Digital Forest Clearance Processes:
   - Use AI and satellite verification to reduce delays while ensuring protection.
8. Training and Capacity Building:
   - Regular training for farmers, forest guards, and local officials on new methods.
9. PPP (Public-Private Partnerships):
   - Involve industries in land restoration through CSR and carbon credit programs.

Conclusion:

New ideas and tools are helping us manage forests, soil, and land better. Sustainable forest and land management is no longer optional-it is essential for environmental health, food security, and climate resilience. Scientific tools like satellite monitoring, drones, and AI-based analytics are transforming the way we monitor and protect natural resources. Government schemes, public-private partnerships, and community engagement play a vital role in making these efforts effective. Challenges like low awareness, poor coordination, and limited access to modern tools still exist, but with integrated policies, education, and innovation, we can ensure that our forests and soils are preserved and restored for future generations. We should keep improving and working together to protect nature and our future.

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INTERCROPPING IS BOON FOR FARMERS: (RABI) WHEAT–MUSTARD INTERCROPPING SYSTEM

1. Introduction

Intercropping is an agricultural practice where two or more crops are grown simultaneously on the same field during a growing season. The crops are arranged in a specific pattern or row ratio so that they interact positively — using sunlight, water, and nutrients more efficiently than when grown alone. It is one of the key components of **sustainable and resource-efficient farming**, particularly important for small and marginal farmers in developing countries.

2. Definition

Intercropping is the growing of two or more crops together on the same piece of land at the same time, with a definite row arrangement or spatial pattern.

This system differs from **mixed cropping**, where seeds of different crops are mixed and broadcast together without a definite pattern.

3. Objectives of Intercropping

- To **maximize utilization of resources** (light, water, and nutrients).
- To **reduce risk** of crop failure due to pests, diseases, or weather.
- To **increase overall productivity and profitability** per unit area.
- To **improve soil fertility and structure** through diversified rooting systems.
- To ensure **food and nutritional security** by producing multiple outputs.

4. Types of Intercropping Systems: Intercropping systems are classified based on time and spatial arrangement of crops:

Type	Description	Example
Row Intercropping	Two or more crops grown simultaneously in distinct rows.	Wheat + Mustard (4:1)
Strip Intercropping	Crops grown in strips wide enough for independent management but close enough for interaction.	Maize + Soybean
Relay Intercropping	A second crop is sown before the first crop is harvested.	Urdbean into standing Maize
Mixed Intercropping	Crops grown together without a specific row arrangement.	Groundnut + Pigeonpea
Temporal Intercropping	Crops differ in maturity periods; one is short-duration and harvested early.	Maize + Mungbean

5. Principles of Intercropping

1. **Complementary Resource Use:** The component crops should differ in growth habits — canopy, rooting depth, nutrient needs, or maturity period — to minimize competition.
2. **Temporal and Spatial Differentiation:** Crops should utilize resources at different times or spatial zones (e.g., deep vs. shallow roots).
3. **Balanced Competition:** Neither crop should suppress the other excessively. Row ratio and planting pattern help maintain balance.
4. **Efficient Management:** The system should allow easy operations like weeding, irrigation, and harvesting.

6. Advantages of Intercropping

A. Agronomic Advantages

- Better **use of sunlight**, water, and nutrients.
- **Suppression of weeds** due to complete ground cover.
- **Reduced pest and disease incidence** through biodiversity.
- **Improved soil fertility** when legumes are involved.

B. Economic Advantages

- **Higher productivity** per unit area (higher Land Equivalent Ratio, LER).
- **Risk reduction:** if one crop fails, the other provides income.
- **Efficient use of labor and farm inputs.**

C. Environmental and Soil Health Benefits

- **Prevents soil erosion** through continuous cover.
- **Enhances biodiversity and ecosystem balance.**
- **Improves soil organic matter** through diversified residues.

7. Disadvantages / Limitations

- Difficult **mechanization** due to mixed crop arrangement.
- Complex **nutrient and water management**.
- Competition may reduce yield of main crop if spacing/nutrients are not managed.
- Harvesting becomes **labor-intensive** in certain systems.

8. Examples of Successful Intercropping Systems

Main Crop	Intercrop	Region / Use	Benefits
Wheat	Mustard	North India	Efficient resource use, high LER
Maize	Soybean	Central India	Balanced C:N ratio, nitrogen fixation
Sugarcane	Onion / Potato	Uttar Pradesh	High economic return
Sorghum	Pigeonpea	Semi-arid tropics	Drought resilience
Cotton	Groundnut	South India	Efficient nutrient and land use

9. Measures of Intercropping Efficiency

Some important indices used to evaluate intercropping systems:

1. **Land Equivalent Ratio (LER):** LER > 1 → intercropping is more productive than sole cropping.
2. **Area Time Equivalent Ratio (ATER):** Adjusts LER for crop duration differences.
3. **Monetary Advantage Index (MAI):** Indicates economic superiority of intercropping.

10. Nutrient and Water Management in Intercropping

- Apply fertilizers **proportionally** based on crop ratio and nutrient demand.
- Prefer **band placement** of fertilizers near each crop row.
- Incorporate **organic manures** and **biofertilizers** to maintain soil fertility.
- Irrigation should be scheduled considering **critical growth stages** of both crops.
- Avoid over-irrigation to prevent waterlogging for shallow-rooted crops.

11. Intercropping Example: Wheat–Mustard System

- **Row ratio:** 4:1 or 6:1 (wheat:mustard).
- **Complementarity:** Wheat (cereal, high N demand) and mustard (oilseed, high S and P demand).
- **Benefits:**
  - Higher total productivity (LER 1.2–1.4).
  - Efficient use of nutrients and sunlight.
  - Reduced pest pressure on wheat.
  - Increased profitability and soil health.

Intercropping—growing two or more crops simultaneously on the same field—is an age-old practice to enhance resource use efficiency and ensure stability in farm income. Among various intercropping systems in northern India and similar agro-ecological regions, the **wheat–mustard intercropping system** is one of the most widely adopted due to its complementary growth habits, efficient resource utilization, and higher economic returns.

Wheat (*Triticum aestivum L.*) is a major cereal crop, while mustard (*Brassica juncea L.*) is an important oilseed crop. Both fit well in rabi (winter) season, but they differ in canopy structure, root depth, and nutrient requirements—making them suitable for intercropping.

Objectives of Wheat–Mustard Intercropping

- To enhance **land use efficiency** and **cropping intensity**.
- To optimize **resource (nutrient, light, and water)** utilization.
- To improve **farm income stability** through crop diversification.
- To minimize **pest and disease risks** by disrupting monoculture cycles.
- To ensure **better soil fertility management** through complementary effects.

Cropping System Design

Crop Geometry and Planting Patterns

Various intercropping arrangements have been tested, and the most common are:

System	**Row Ratio (Wheat : Mustard)**	**Description**
4:1	Four rows of wheat followed by one row of mustard	Common and balanced system
6:1	Six rows of wheat followed by one row of mustard	Favorable for high wheat yield
8:2	Eight rows of wheat and two of mustard	Suitable for irrigated areas
Paired-row planting	Two rows of wheat paired with one mustard row	Ensures better light distribution

Seed rate adjustment:

- **Wheat:** 75–80% of the sole crop seed rate (i.e., ~80–90 kg/ha).
- **Mustard:** 80% of the sole crop rate (i.e., ~4–5 kg/ha).

Sowing Time

Both crops are generally sown **from mid-October to mid-November**, depending on regional climate and preceding crop harvest (usually rice).

3.3. Sowing Method

- Use a **seed-cum-fertilizer drill** or **multi-crop planter** for uniform row spacing.
- Mustard should be sown slightly deeper (2–3 cm) than wheat (2 cm).
- Ensure proper seed placement to avoid competition in the early stages.

Agronomic Management Practices

Land Preparation

- Prepare a fine seedbed with 2–3 ploughings and one harrowing.
- Level the field properly for uniform irrigation and drainage.
- Incorporate 8–10 tons/ha of **well-decomposed FYM (farmyard manure)** or compost before final harrowing to improve soil structure and microbial activity.

Irrigation Management

- Wheat requires **4–6 irrigations**, while mustard requires **3–4** depending on rainfall.
- In intercropping, schedule irrigation based on the **critical stages**:
  - Wheat: Crown root initiation (CRI), tillering, jointing, flowering, grain filling.
  - Mustard: Flowering and pod formation stages.
- Use **border or check basin irrigation** ensuring water does not stagnate near mustard rows (which are sensitive to waterlogging).

Weed Management

- Apply **pre-emergence herbicide** such as pendimethalin (1.0 kg a.i./ha) within 2–3 days after sowing.
- One **hand weeding** or **interculture operation** at 25–30 days after sowing improves weed control.
- Mustard’s broader leaves later suppress weeds effectively.

Nutrient Management

Nutrient Requirement and Complementarity

Wheat and mustard differ in nutrient uptake patterns:

- **Wheat:** High nitrogen (N) demand for vegetative growth.
- **Mustard:** Moderate N but higher sulfur (S) and phosphorus (P) requirement for oil synthesis.

When intercropped, their nutrient demands **complement** each other, leading to efficient use of soil nutrients.

Recommended Fertilizer Dose (for

intercropping system)

Crop	Nitrogen (N)	Phosphorus (P_2O_5)	Potassium (K_2O)	Sulfur (S)
Wheat	100–120 kg/ha	50–60 kg/ha	40 kg/ha	—
Mustard	80 kg/ha	40 kg/ha	40 kg/ha	30 kg/ha

For intercropping, apply nutrients **on area proportion basis** depending on row ratio. For example, in a 4:1 system: 80% of wheat dose + 20% of mustard dose.

Method and Time of Application

- Apply **½ N and full P, K, and S** as basal at sowing.
- The remaining ½ **N** should be top-dressed in two equal splits at:
  - **First irrigation (CRI stage)** and
  - **Booting or flowering stage** of wheat.
- For mustard, basal placement near seed zone ensures better nutrient uptake.

Organic and Biofertilizer Use

- Incorporate **FYM or vermicompost (5–10 t/ha)** for sustained soil fertility.
- Use **Azotobacter or Azospirillum** inoculants for wheat and **Rhizobacteria or PSB (Phosphate Solubilizing Bacteria)** for mustard.
- Application of **sulfur through gypsum (250–300 kg/ha)** or **elemental S (20–25 kg/ha)** enhances oil content in mustard and yield in wheat.

Cropping System Productivity and Economics

- The **Land Equivalent Ratio (LER)** for wheat–mustard intercropping typically ranges from **1.2 to 1.4**, indicating 20–40% better land-use efficiency than sole cropping.
- Mustard contributes significantly to **gross returns** due to its high market price.
- Net returns and **benefit-cost ratio** are usually highest in **4:1 or 6:1 wheat–mustard systems** under proper nutrient and water management.

Environmental and Soil Health Benefits

- **Reduced nutrient losses** due to complementary root systems.
- **Improved soil fertility** through organic matter recycling.
- **Reduced pest incidence**, as mustard acts as a trap crop for certain pests.
- **Efficient water use** due to differential rooting patterns.

Conclusion

The wheat–mustard intercropping system is a sustainable and profitable practice for rabi season farming, especially in Indo-Gangetic plains and similar agro-climatic zones. Proper **row arrangement**, **balanced nutrient management**, and **timely irrigation** are key to maximizing productivity. Integration of organic manures and biofertilizers further enhances soil health and ensures long-term sustainability.

Key Recommendations

- Adopt **4:1 or 6:1 wheat–mustard row ratio** for optimum performance.
- Apply **site-specific nutrient management** combining organic, inorganic, and biofertilizers.
- Schedule irrigation based on **critical crop growth stages**.
- Monitor weeds and pests early to prevent yield loss.

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DISEASES AND INSECT PESTS IN MUSTARD AND THEIR MANAGEMENT

1. Introduction

Mustard (*Brassica juncea*), commonly known as *sarson* or *rai*, is one of the most important oilseed crops in India. Its seeds contain 35–40% oil and 25–30% protein, making it valuable both for human consumption and livestock feed. Mustard oil is widely used for cooking, while the cake left after oil extraction is an excellent source of animal feed.

India is one of the largest producers of mustard in the world, with major growing states including **Rajasthan, Haryana, Uttar Pradesh, Madhya Pradesh, Gujarat, and West Bengal**. Despite its importance, mustard productivity in farmers' fields is often lower than potential yields. One major reason for this yield gap is the **damage caused by diseases and insect pests**.

Diseases and insects attack mustard plants at all stages — from seedling to harvest — and if not controlled in time, they can cause yield losses ranging from **20% to 70%**. Therefore, understanding these problems and managing them in a sustainable manner is essential for higher yield and income.

2. Importance of Managing Diseases and Pests

Healthy mustard crops produce bold seeds with high oil content. However, when diseases and insects attack, they reduce leaf area, spoil flowers and pods, and lower seed quality. Farmers often try to control them only with chemical sprays, but overuse of pesticides increases costs and can harm pollinators, natural enemies, and even human health.

The best approach is **Integrated Pest and Disease Management (IPDM)** — a combination of cultural, biological, and chemical methods used together to keep pests and diseases below harmful levels. This system reduces cost, protects the environment, and ensures safe, high-quality mustard production.

3. Major Diseases of Mustard

Mustard suffers from several fungal, bacterial, and viral diseases. Among them, a few cause most of the economic losses.

3.1 Alternaria Blight

- **Causal organism:** *Alternaria brassicae* and *A. brassicicola*
- **Symptoms:** Small dark brown circular spots appear on leaves, stems, and pods. The spots enlarge with concentric rings, and leaves dry up early. Infected pods give small, shriveled seeds.

- **Favorable conditions:** Cool and humid weather, cloudy days, and continuous cultivation of mustard in the same field.
- **Management:**
  - Use resistant varieties like *Pusa Bold*, *Varuna*, *Pusa Mahak*, or *Pusa Tarak*.
  - Avoid late sowing and water stress.
  - Spray **mancozeb (0.25%)** or **tebuconazole (0.1%)** two to three times at 15-day intervals starting from flowering.
  - Remove and burn infected crop residues.

3.2 White Rust

- **Causal organism:** *Albugo candida*
- **Symptoms:** White pustules appear on the lower surface of leaves and stems. When the infection reaches flowers, it causes "staghead" formation — twisted and malformed inflorescences without seeds.
- **Favorable conditions:** Cool, moist weather and waterlogged soil.
- **Management:**
  - Grow tolerant varieties (*Kranti*, *Pusa Mustard 21*).
  - Ensure proper drainage and avoid excess irrigation.
  - Spray **metalaxyl + mancozeb (0.25%)** at early flowering.
  - Rotate mustard with cereals or pulses for 2–3 years.

3.3 Downy Mildew

- **Causal organism:** *Peronospora parasitica*
- **Symptoms:** Yellow spots appear on the upper surface of leaves, and grayish downy growth occurs on the underside. Leaves turn pale and drop early.
- **Management:**
  - Avoid high humidity and close spacing.
  - Use disease-free seeds.
  - Spray **cymoxanil + mancozeb (0.25%)** at the first appearance.

3.4 Sclerotinia Stem Rot

- **Causal organism:** *Sclerotinia sclerotiorum*
- **Symptoms:** Water-soaked lesions appear on stems; later, the stem becomes hollow with black hard bodies (sclerotia) inside. Plants break and fall at the base.
- **Favorable conditions:** Cool, wet weather and continuous mustard cultivation.
- **Management:**
  - Follow **crop rotation** (avoid mustard for 3 years in the same field).
  - Treat seed with **carbendazim (2 g/kg)**.
  - Apply **Trichoderma harzianum** to soil (2.5 kg/ha mixed with FYM).
  - Spray **carbendazim (0.1%)** at 50% flowering stage.

3.5 Powdery Mildew

- **Causal organism:** *Erysiphe cruciferarum*
- **Symptoms:** White powdery growth on leaves and pods, reducing photosynthesis and seed weight.
- **Management:**
  - Avoid late sowing.
  - Dust with **sulphur (25 kg/ha)** or spray **wettable sulphur (0.25%)**.

3.6 Bacterial Black Rot

- **Causal organism:** *Xanthomonas campestris pv. campestris*
- **Symptoms:** V-shaped yellow patches start at leaf edges and move inward. Veins turn black, and leaves dry up.
- **Management:**

- Use hot-water treated seed (50°C for 30 minutes).
- Apply **copper oxychloride (0.3%)** spray.
- Follow 3-year rotation with non-cruciferous crops.

3.7 Viral Diseases (Turnip Mosaic Virus)

- **Symptoms:** Mottling and mosaic pattern on leaves, stunted growth, malformed pods.
- **Transmission:** Mainly by aphids.
- **Management:**
  - Control aphids early.
  - Remove infected plants.
  - Avoid planting near already infected fields.

4. Major Insect Pests of Mustard

Several insects attack mustard during different growth stages.

4.1 Mustard Aphid (*Lipaphis erysimi*)

- **Nature of damage:** Aphids suck sap from young leaves, buds, and pods, causing curling and yellowing. Heavy infestation leads to poor pod formation and sticky honeydew on plants.
- **Favorable conditions:** Cool, dry weather (December–February).
- **Management:**
  - **Early sowing** (October) helps escape infestation.
  - Encourage predators like **ladybird beetles** and **green lacewings**.
  - Spray **imidacloprid (0.03%)** or **thiamethoxam (0.025%)** when 15–20 aphids are seen per 10 cm shoot tip.
  - Avoid spraying during flowering to protect bees.

4.2 Painted Bug (*Bagrada hilaris*)

- **Nature of damage:** Adults and nymphs suck sap from seedlings and pods, causing wilting and seed shriveling.
- **Management:**
  - Keep field clean and remove weeds (especially *Cleome* species).
  - Treat seed with **imidacloprid (5 ml/kg)**.
  - Spray **malathion (0.05%)** if 1–2 bugs per seedling are seen.

4.3 Leaf Webber (*Crocidolomia binotalis*)

- **Nature of damage:** Caterpillars web leaves together and feed inside; later attack buds and pods.
- **Management:**
  - Handpick and destroy webbed leaves.
  - Set up **light traps** to catch moths.
  - Spray **Bacillus thuringiensis (Bt)** or **spinosad (0.02%)**.

4.4 Pod Borer (*Helicoverpa armigera*)

- **Nature of damage:** Larvae bore into pods and eat developing seeds.
- **Management:**
  - Use **Trichogramma chilonis** (50,000/ha) to kill eggs.
  - Spray **NPV (Nuclear Polyhedrosis Virus)** or **emamectin benzoate (0.0025%)**.

4.5 Other Minor Pests

- **Flea beetles:** Chew small holes in leaves; control by spraying **malathion (0.05%)**.
- **Sawfly:** Larvae cut leaves; handpick or spray **chlorpyriphos (0.05%)** if severe.

5. Integrated Pest and Disease Management (IPDM)

Integrated management combines different methods to prevent and control diseases and pests in an eco-friendly way.

5.1 Cultural Practices

- Rotate mustard with cereals or pulses.
- Use clean, certified seed.
- Sow early (mid-October) to avoid aphids.
- Maintain 30 × 10 cm spacing for proper aeration.
- Remove and destroy crop residues.
- Avoid excess nitrogen fertilizer.
- Maintain good drainage and balanced nutrition.

5.2 Biological Control

- Treat seed with **Trichoderma harzianum** (6 g/kg) to suppress soil fungi.
- Spray **Pseudomonas fluorescens** or **neem extract (5%)** to manage foliar diseases and aphids.
- Encourage **ladybird beetles, lacewings, and syrphid flies** for aphid control.
- Use **Beauveria bassiana** and **Metarhizium anisopliae** against caterpillars.

5.3 Botanical Pesticides

- Use **neem seed kernel extract (5%)**, **neem oil (2%)**, or **pongamia oil (2%)** against sucking pests and caterpillars.
- These are safe for bees and natural enemies.

5.4 Chemical Control (Need-Based Only)

Use chemicals only when pest levels cross the **Economic Threshold Level (ETL):**

Pest/Disease	ETL	Recommended Spray
Aphid	15–20 aphids/10 cm shoot	Imidacloprid 0.03% or Thiamethoxam 0.025%
Painted bug	1–2 bugs/seedling	Malathion 0.05%
Pod borer	5 larvae/10 plants	Spinosad 0.02% or Emamectin benzoate 0.0025%
Alternaria blight	5% leaf area infected	Mancozeb 0.25% or Tebuconazole 0.1%
White rust	10% plants infected	Metalaxyl + Mancozeb 0.25%

Always spray in the **morning or evening**, avoid spraying during full bloom, and follow **pre-harvest intervals** (15 days minimum).

5.5 Community and Ecological Approach

When farmers in a village follow IPDM together:

- Pest population remains low.
- Chemical costs reduce.
- Pollinators and natural enemies thrive.

Forming **Farmer Field Schools (FFS)** or IPM clubs helps in sharing experiences and training.

6. Role of Weather and Climate Change

Mustard pests and diseases depend heavily on weather. Cool and moist conditions increase fungal diseases, while dry weather favors aphids. With changing climate patterns — irregular rainfall, warmer winters — pest behavior is shifting. Farmers should therefore:

- Follow weather forecasts.
- Observe crop fields regularly.
- Take preventive action at the first sign of infection.

Mobile apps and advisory services from agriculture departments now help farmers receive early pest warnings and management tips.

7. Modern Tools for Sustainable Management

- **Soil testing and balanced fertilization** reduce disease pressure.
- **Drone spraying** allows uniform and safe pesticide application.
- **Digital pest monitoring** through sensors or mobile reporting helps forecast outbreaks.
- **Bio-fertilizers and composting** improve soil health and natural disease resistance.

8. Benefits of Integrated Management

Type of Benefit	Description
Economic	15–25% higher yield, lower pesticide cost
Environmental	Reduced pollution, healthier soil and water
Health & Safety	Less chemical exposure to farmers
Sustainability	Balanced ecosystem, protection of pollinators

9. Future Outlook

To make mustard farming more profitable and sustainable, emphasis should be placed on:

1. **Developing resistant and high-yielding varieties** through breeding.
2. **Promoting biological and botanical solutions** over chemicals.
3. **Using digital and climate-smart tools** for early warnings.
4. **Training farmers** through demonstrations and field schools.
5. **Encouraging group action** and eco-friendly practices.

10. Key Take-Home Messages for Farmers

✅ Use **healthy seed** and follow **crop rotation**.

✅ Sow **early** to escape aphid attack.

✅ Keep the **field clean and weed-free**.

✅ Encourage **natural enemies** like ladybird beetles.

✅ Spray chemicals **only when necessary** and in correct dose.

✅ Always protect **bees and beneficial insects**.

✅ Follow **Integrated Pest and Disease Management (IPDM)** for sustainable mustard production.

11. Conclusion

Mustard is a key crop for Indian farmers, but its yield is threatened by many diseases and insects. Blind use of pesticides increases costs and harms the environment. By following the principles of **Integrated Pest and Disease Management (IPDM)** — using resistant varieties, good agronomic practices, biological control, and need-based pesticide use — farmers can protect their crops effectively, reduce losses, and improve income sustainably.

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Control Measures Against Lentil Pests and Diseases

1. Introduction

Lentil is one of the most important pulse crops globally, valued for its high protein content and ability to improve soil fertility through nitrogen fixation. However, its productivity is constrained by a wide range of pests (insects, nematodes) and pathogens (fungi, bacteria, viruses). Losses can be significant if control measures are inadequate. Effective management requires accurate disease/pest identification, understanding of ecology, timely interventions, and integrated strategies that combine multiple approaches.

2. Major Pests and Diseases of Lentil

Below are some of the key pests and diseases affecting lentils, with symptoms, causal organisms, and contributing factors.

2.1 Diseases

Disease	Causal Agent(s)	Symptoms / Damage	Favorable Conditions
Ascochyta blight	*Ascochyta lentis* (or related species)	Tan to brown lesions on leaves, stems, pods; can cause defoliation, pod infection, seed rotting.	Cool, humid weather; seed-borne inoculum; presence of infected residue.
Anthracnose	*Colletotrichum truncatum*	Dark, sunken lesions often on stems; can girdle stems; loss of pods; yield reduction.	Presence of wet foliage, infected residue; seed transmission; favorable moisture.
Botrytis grey mould (Grey mould)	*Botrytis cinerea*, *Botrytis fabae*	Leaf spots, mould on flowers, pods; under high humidity or dense canopy; seed discoloration; damage during pre-harvest or maturation.	
Sclerotinia white mould (Stem or Pod Rot)	*Sclerotinia sclerotiorum*	White mould / mycelial growth; stem rot; pod rot; lodging; severe yield loss.	
Root rots and wilts	*Fusarium* spp., *Rhizoctonia* spp., *Pythium* spp., *Aphanomyces*, etc.	Seedling damping-off; wilted plants; root decay; stunted growth; yellowing; plant death.	
Rust	*Uromyces viciae-fabae*	Pustules / rust coloured spots on leaves, leaf drop; reduces photosynthesis and plant vigor; yield and seed quality losses.	
Viruses and virus-vectored diseases	Alfalfa mosaic, bean/pea leaf roll, bean yellow mosaic, etc.	Mottling, mosaic, stunting, leaf distortion, reduced yield. Vector insect transmission common.	
Other foliar pathogens	Stemphylium blight, powdery mildew, etc.	Leaf lesions, defoliation under favourable conditions.	

2.2 Insect Pests

Some of the significant insect pests include:

- Aphids (e.g., *Aphis craccivora*, *Acyrthosiphon pisum*) – sap sucking; vector viruses.
- Pod borers – caterpillars bore into pods, destroy seeds.
- Cutworms, wireworms, seedcorn maggots – attack seedlings, roots, reduce stand.
- Thrips, leaf weevils, grasshoppers – defoliate, damage leaves or flowers.

3. Principles of Control

To manage these pests and diseases effectively, the following general principles apply:

1. **Prevention is better than cure** – reduce initial inoculum or pest pressure.
2. **Integrated Pest Management (IPM)** – combining cultural, biological, varietal, chemical methods.
3. **Timely action** – early detection, monitoring and threshold-based interventions.
4. **Use of healthy seeds and resistant varieties** – a foundational strategy.
5. **Good crop hygiene and field sanitation** – removal of residues, weed control, crop rotation.
6. **Environmental fit** – matching sowing dates, crop management to environmental risk (moisture, temperature, humidity).

4. Cultural / Agronomic Measures

These are foundational, low-cost, sustainable methods to reduce disease/pest incidence or severity.

4.1 Use of Disease-/Pest-Free Seed and Certified Seed

- Always use certified, disease-free seed. Seed testing for seed-borne pathogens (e.g., Ascochyta, anthracnose, rust) helps avoid introducing the disease into the field.
- Seed treatment (fungicides / biologicals) to protect against seed-borne and early soil-borne pathogens.

4.2 Crop Rotation

- Rotate lentil with non-host crops. Avoid planting lentil in the same field repeatedly; aim for 3–4 year rotations.
- Rotation helps break the disease cycle by depriving pathogens or pests (especially soil-borne) of hosts.

4.3 Soil and Field Hygiene

- Deep ploughing (or summer ploughing) to expose and reduce survival of soil pathogens.
- Removal and destruction of infected crop residues to reduce inoculum.
- Ensure well drained soil to avoid waterlogging, which favors root rots and fungal disease.

4.4 Proper Sowing Date and Density

- Adjusting sowing date to avoid high disease pressure periods. Delayed or early sowing as per local climatic risk.
- Adequate spacing to improve air circulation and reduce humidity in canopy, which lowers fungal disease and mould incidence.

4.5 Weed Control

- Weeds act as alternate hosts for many pathogens and vectors; they also contribute to humidity in field microclimate. Frequent weeding, removal of volunteer plants is important.

4.6 Soil Amendments and Micronutrients

- Nutrient management, particularly correcting deficiencies of micronutrients such as Boron, Zinc, etc. It can reduce disease vulnerability.
- Organic matter additions (well decomposed farmyard manure) can

improve soil health and support beneficial microbial populations.

4.7 Physical Methods

- Soil solarization: covering soil with transparent plastic sheets during hot periods to kill soil-borne pathogens/pests.
- Proper drainage; avoiding water puddling.

5. Genetic / Varietal Resistance

A very effective strategy, both sustainable and cost-efficient, is deploying varieties that are resistant or tolerant to pests/diseases.

- Use lentil cultivars with known resistance to Ascochyta blight, Fusarium wilt, root rots, rust, etc.
- Breeding programs (e.g., ICARDA and national programs) have developed varieties with improved resistance to Fusarium wilt, ascochyta, etc.
- Keep varietal diversity: using different varieties to reduce risk of widespread damage if one becomes susceptible under changing conditions.

6. Biological Control

Using beneficial organisms to suppress pests and pathogens, or to reduce their survival or reproduction.

- Use of antagonistic fungi and bacteria such as *Trichoderma spp.*, *Pseudomonas fluorescens*, *Bacillus subtilis*, etc., especially against Fusarium wilt and root rots.
- Conservation and augmentation of natural enemies of insect pests: predators (ladybird beetles, lacewings), parasitoids (Aphidius spp., Aphelinus), entomopathogenic nematodes, etc.
- Use of biopesticides: neem, neem derivatives, other botanicals for certain pests like aphids or when chemical control is undesirable. \

7. Chemical Control

When justified (i.e. when pest/disease pressure is high, threshold crossed, and other methods insufficient), fungicides, insecticides, etc. are used, carefully, as part of IPM to delay resistance and minimize environmental harm.

7.1 Fungicides

- For **Ascochyta blight / Anthracnose**: fungicide sprays at early flowering to early pod set are critical. Use registered products for your region. Seed treatment fungicides also help.
- For **Botrytis grey mould**: fungicide applications prior to canopy closure; possibly repeated sprays in humid weather.
- For **Rust**: seed treatments, foliar sprays such as Mancozeb, copper fungicides, etc. Timing is early appearance of symptoms.

7.2 Insecticides / Pest Control Compounds

- For **Aphids**: systemic or contact insecticides; early monitoring; sprays when infestation crosses threshold.
- For **Pod borers**: insecticides applied at appropriate stages (flowering / early pods) to prevent damage.
- For **Seedling pests** (cutworms, maggots, etc.): seed treatment with insecticide; soil treatment; ensuring seedbed preparation to reduce pest habitat.

7.3 Seed Treatment

- Fungicides: Thiram, Captan, carboxin, etc., to protect against seed-borne pathogens and early root rots.
- Insecticide coatings for seed to reduce early attack by soil pests.

8. Monitoring, Scouting, and Decision Thresholds

Effective control depends on knowing *when* action is needed.

- Regular field scouting: during vegetative, pre-flowering, flowering, and pod set stages.
- Use of disease risk models or decision support tools (weather, moisture, previous history) to predict when disease pressure may surge.
- Thresholds for action: e.g. when % leaflets showing lesions, or when lower canopy infected beyond a point.

9. Integrated Pest & Disease Management (IPDM) for Lentil

Putting all the above together into a coherent system.

1. **Field Selection & Preparation**
    - Choose well-drained soils; avoid fields with history of seed-borne disease.
    - Summer ploughing to reduce pathogen load.
2. **Seed Quality**
    - Certified, healthy, disease-free; treated for both fungal and insect issues.
3. **Varietal Choice**
    - Use resistant or tolerant varieties suitable to local growing conditions.
4. **Sowing Practices**
    - Optimal date and spacing; avoid sowing when conditions favor disease.
    - Use proper seed depth.
5. **Crop Rotation and Crop Sequence**
    - Include non-legume, non-host crops; avoid continuous legumes.
6. **Sanitation & Hygiene**
    - Remove infected residues; weed control; hygiene for tools; clean equipment.
7. **Biological Control & Beneficials**
    - Encourage natural enemies; apply biocontrol agents; use botanicals where appropriate.
8. **Chemical Control as Last Resort & Strategically**
    - Apply fungicides/insecticides only when necessary, using proper dosage, timing, and rotating modes of action.
9. **Environmental / Weather Management**
    - Avoid waterlogging; ensure good drainage; manage canopy density; avoid situations that promote humidity; timely harvest to avoid disease build-up.
10. **Post-Harvest Handling**
    - Dry seeds properly; store at suitable moisture; sanitize storage; protect against storage pests (e.g. bruchids).

10. Case Examples & Specific Practices (India / Similar Regions)

Below are practices reported in India or similar agro-ecologies, which illustrate how the general strategies are adapted locally.

- **Seedling mortality / Collar rot**: In India, delaying sowing until mid-November helps reduce seedling mortality. Seed treatment using fungicides like Thiram, Vitavax, or others is effective.
- **Rust control**: Growing resistant/tolerant varieties (e.g., DPL-15, Narendra Lentil-1, Pant L series, etc.), combined with 1-2 sprays of Mancozeb 75 WP (at about 0.2 %) at ~50 days after sowing.
- **Pod borer control**: Using insecticides like Chlorantraniliprole, Flubendiamide, Indoxacarb, Spinosad in specified doses in local units (e.g. ml per 200 liters of water per acre).

- **Wilt and root rot**: Application of biological agents like *Trichoderma viride*, use of resistant varieties (PL 406, PL 639, PL 234), delayed sowing, certified seed, deep ploughing, and soil solarization.

11. Challenges and Constraints in Control

- **Weather unpredictability**: Rain, humidity, temperature affect disease development; unanticipated weather makes timing of sprays difficult.
- **Pathogen/pest resistance**: Overuse of chemicals may lead to resistance, necessitating rotation of modes of action.
- **Availability of resistant varieties**: Locally adapted, disease-resistant varieties may not always be available; breeders may lag.
- **Economic constraints**: Costs of fungicides, insecticides, biocontrol agents, quality seed, etc. may be high for small farmers.
- **Knowledge, extension gaps**: Identification of diseases/pests, timing of intervention, proper dosages often require good advisory support.
- **Environmental and regulatory considerations**: Safe usage, IPM compliance, residue limits, etc.

12. Recent Advances and Research Directions

- **Molecular diagnostics and early detection**: Use of molecular tools to detect pathogens in seed or soil before symptoms appear.
- **Better resistant germplasm and marker-assisted breeding**: Development of cultivars with resistance to multiple pathogens and pests.
- **Improved biocontrol agents**: More effective strains, consortia of organisms that act synergistically.
- **Decision support systems / forecasting tools**: Based on weather data, remote sensing, disease models to help farmers know when risk is high.
- **Reduced risk chemicals / safer formulations**: Fungicides/insecticides with lower environmental impact, better safety, better efficacy.

13. Summary of Control Strategy

To summarize, an effective control programme for lentil pests and diseases should include:

1. **Pre-planting**: select clean seed, treat seed, choose resistant variety, field preparation, crop rotation.
2. **Establishment**: proper sowing date, spacing, nutrient management, weed control.
3. **Growth period**: monitoring, sanitation, biological control, chemical interventions if thresholds exceeded.
4. **Harvest and post-harvest**: timely harvest, proper drying, storage hygiene.

Each component reduces either the pest/disease inoculum, or makes crop less favourable for its development, or intervenes to interrupt pest/disease life cycle. The integration of multiple such strategies tends to give sustainable control, reduce dependence on chemical inputs, and reduce environmental / economic risks.