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AgriGate

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An International Multidisciplinary Monthly e-Magazine

PM MODI EMPOWERS FARMERS DHAN DHANYA KRISHI YOJANA

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From the Desk of Editor-in-chief

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I would like to introduce the launch of **"AgriGate - An International Multidisciplinary Monthly e-Magazine Volume 05 Issue No. 08 – August 2025"** with immense pleasure ourteam is privileged to dedicate this issue to **freedom fighters and farmers of India**. India celebrates **Independence Day on 15th, August** of every year. As of this day, India got freedom. It makes us remind about a new beginning, the beginning of a new era and freedom to write. We also dedicate this issue to Agricultural youths. The **International Youth Day** is celebrated on **12 August** around the globe to focus on the development and protection of youth in society.

The main objective of the magazine is to provide a publishing platform to young researchers and scientists as well as an information hub for the enthusiast, progressive farmer and also common readers. We envisage providing an online platform that appreciates illuminating articles on various topics related to agriculture and allied sciences monthly that will appraise and update the students, farming community and the whole society at large on the updates in agriculture.

Last but not the least, I wholeheartedly thank the editorial team, authors as well as anonymous reviewers for contributing to the release of this issue.

Our team welcomes your constructive feedback and suggestions to improve delivering fruitful content to hungry minds.

Dr R Shiv Ramakrishnan
Editor-in-chief
AgriGate Magazine

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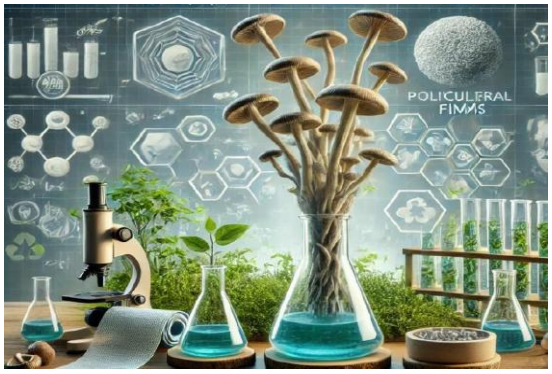

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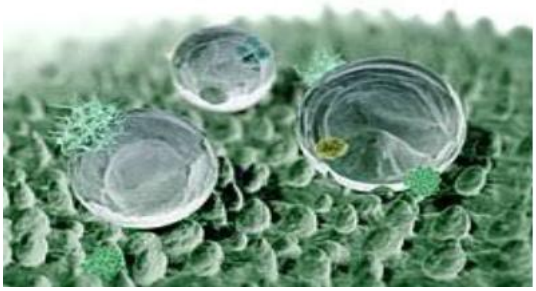

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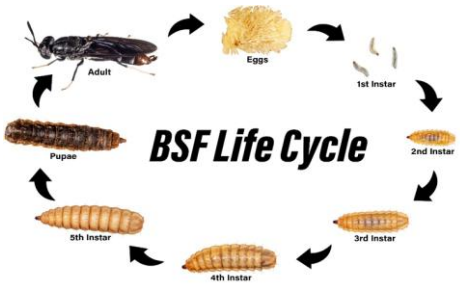

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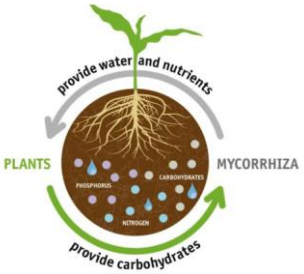

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BEYOND HONEY: A GUIDE TO HANDLING BEESWAX AND BEE POLLEN

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Abstract

Honey bee byproducts include honey, beeswax, bee pollen, bee venom, and royal jelly. Beeswax is an oily substance secreted by worker bees for comb construction. Bee pollen is a mixture of floral pollen, nectar, and saliva, prepared by worker bees and used as food. Both beeswax and bee pollen offer several benefits to humans. However, due to a lack of sufficient knowledge about their extraction and processing, many beekeepers limit their operation to honey production. This article explains the various steps involved in extracting and processing beeswax and bee pollen.

Keywords: beeswax, bee pollen, honey, nectar and food

Introduction

Honeybee colonies produce several valuable byproducts, including honey, beeswax, bee pollen, propolis, royal jelly, and bee venom.

Beeswax is initially a clear, colorless oily secretion produced by special glands located on the underside of a worker bee's abdomen. When exposed to air, this secretion solidifies into wax scales. Chemically, beeswax is composed primarily of esters (70-80%), hydrocarbons (10-20%), and free fatty acids (12-14%).

Bee pollen is a blend of flower pollen, nectar, and bee saliva. Bees store this mixture in the hive's comb cells, where it undergoes fermentation before becoming a digestible food source for the colony known as bee bread.

In India, many apiarists/beekeepers focus only on one byproduct, honey. This is because collecting honey from the comb is straightforward and requires less skill and machinery. In

addition, due to its taste, nutritional value, and medicinal properties, honey is in high global demand. Its demand and supply are relatively balanced, and preexisting market channels make it easier to sell. Moreover, honey extraction causes minimal damage to bees. For these reasons, apiculture in India is largely limited to honey production. However, in reality, other bee products are often more valuable than honey. Due to various factors, such as a lack of awareness about the uses of other bee products (beeswax, bee pollen, propolis, royal jelly, and bee venom), limited knowledge of extraction and processing techniques, lack of equipment, and the absence of established market channels, Indian beekeepers remain focused primarily on honey. This article explains the processing of bee products, especially beeswax and bee pollen and the various valuable products derived from them.

Beeswax products and processing (Bradbear et al., 2009)

Beeswax is generally more expensive than honey due to its versatility and limited production. Interestingly, just 1 kilogram of beeswax found in honeycomb cells can support the storage of approximately 22 kilograms of honey, pollen, and brood. Unlike honey, beeswax is not consumed as food, so it does not require elaborate storage methods. Globally, around 40% of commercially traded beeswax is utilized in the cosmetics industry, 30% goes into pharmaceuticals, and about 20% is used for making candles. The remaining 10% finds diverse applications, including model making, sculpture casting, car and furniture polish, shoe polish, grafting waxes, lubricants, insulation in electronic devices, waterproof seals for bottles and containers, and even in the production of crayons. At room temperature, beeswax is solid. It becomes brittle below 18 °C and softens between 35 °C and 40 °C. Its melting point is approximately 64.5 °C.

Common Sources of Beeswax: Cappings from honey extraction, Scrappings from hive maintenance, Old and damaged combs.

Equipment Used for Beeswax Processing: Wax and honey separator, Solar wax melter, Steam wax melter, Wax press, Electric melter.

Procedure

1. **Procurement of Raw Material:** Collect beeswax-containing materials such as old combs, cappings, and scrapings.
2. **Separation of Honey (if applicable):** If the source is a honeycomb, extract honey using a honey extractor to separate it from the wax sheets.

3. **Initial Cleaning:** Soak the emptied combs in warm water to remove residual honey, pollen, and other impurities.
4. **Fragmentation:** Break the combs into smaller pieces to aid in the melting process.
5. **Melting Setup:** Place the wax pieces into a pan and add a sufficient amount of water.
6. **Heating and Stirring:** Heat the mixture while stirring continuously to melt the wax evenly.
7. **Wax Liquefaction:** As the wax melts, it turns into a molten liquid.
8. **Filtration:** Pour the molten mixture through a cloth filter and squeeze it thoroughly into a container filled with warm water.
9. **Separation:** The filtered wax mixes with the warm water, separating out from any solid debris.
10. **Cooling and Solidification:** Let the mixture sit undisturbed for about 12 hours. The wax, being lighter, solidifies and forms a disc that floats above the water due to the density difference.
11. **Collection:** Carefully collect the wax disc from the surface.
12. **Re-filtration:** Repeat the entire process two to three times using cloths with different pore sizes to ensure thorough cleaning.
13. **Final Purification:** Once the wax disc appears free from dust and contaminants, it is collected and stored for further use.

Precautions

When handling beeswax, several precautions must be taken to maintain its quality. Heating beeswax above 85°C should be avoided, as excessive heat can lead to discoloration. It is essential to use clean water at every stage of the process; using hard water is discouraged because it contains lime, which can react with the wax and cause saponification, reducing the quality of the final product. The containers used for melting or extracting beeswax should be made of enamel, nickel, plastic, or stainless steel. This is because beeswax is mildly acidic and can chemically react with metals such as aluminium, brass, copper, zinc, pewter, and tinplate, which may contaminate the wax. Additionally, it is important not to mix dark-colored combs with light-colored ones, as doing so can significantly reduce the overall quality and appearance of the wax.

Bee pollen products and processing (Somerville, 2012)

Bee pollen serves two primary purposes: it can be returned to the hive as a nutritional supplement for honey bees, and it is also consumed by humans due to its antioxidant, anticancer, antimicrobial, and hepatoprotective properties. The nutritional value of pollen varies depending on the plant species it is collected from, as different plants produce pollen with varying levels of lipids, minerals, and vitamins. For instance, pollen from pine trees is considered to have low nutritional value, containing only about 7% protein. In contrast, honey bees require pollen with approximately 20% protein content to meet their dietary needs. A healthy and active bee colony can consume up to 50 kilograms of pollen annually.

To collect bee pollen, beekeepers use specialized devices known as pollen traps. These traps are designed to encourage returning forager bees, carrying pollen on their bodies and legs, to enter the hive through narrow openings. As the bees pass through, the pollen is gently scraped off and collected on a tray. An effective pollen trap should be capable of collecting 60% to 80% of the pollen without causing excessive stress to the bees. It should also be easy to install, remove, and clean, while protecting the collected pollen from sunlight, moisture, and contamination. Some of the commonly used types of pollen traps include Sundance traps, front porch entrance traps, and wooden hive-mounted traps.

Procedure

Unlike honey, bee pollen is highly susceptible to contamination by mould, fungi, and bacteria. Therefore, when bee pollen is intended for human consumption, maintaining high-quality standards is essential. Proper processing and storage are critical steps to preserve its nutritional value and safety. The key stages of bee pollen processing include drying, cleaning, and storing.

1. **Drying**: Freshly collected pollen contains between 7% and 21% moisture, which can promote the growth of mould and lead to spoilage. To prevent this, pollen should be dried in the shade at temperatures not exceeding 45°C until the moisture content is reduced to between 2.5% and 6%.
2. **Cleaning**: Once dried, the pollen is cleaned using sieves selected according to the size of the pollen grains. This step helps in removing debris and foreign particles to ensure purity.

3. **Storing**: After drying and cleaning, the pollen should be stored in airtight containers. Since pollen is hygroscopic by nature, it readily absorbs moisture from the air, which can compromise its quality. Airtight storage helps preserve its condition and extend shelf life.

Precautions

Pollen collection should be carried out when bee colonies are strong and there is abundant pollen available in the environment. For pollen intended for human consumption, traps should be checked and emptied every 2 to 3 days to prevent spoilage. For bee feeding, pollen can be collected at intervals of 5 to 7 days. Pollen used for bee feed should ideally be used within 9 to 12 months of collection. It's important to note that drying pollen can reduce its nutritional value compared to freezing. Therefore, pollen meant for bee feeding should be packed in airtight containers and frozen immediately after collection, without drying, to retain its full nutritive properties.

Conclusion

Every farmer engaged in beekeeping should be adequately trained in bee byproducts, their uses, and the methods of extraction, processing, and storage. This can be achieved by conducting skill development and hands-on training programs through farmer field schools, facilitated by NGOs and extension professionals. The government should support apiarists by providing subsidies for beehives and the equipment required for extraction and processing. Additionally, the government should help establish market channels by creating platforms where apiarists and buyers can freely communicate with each other. When farmers receive proper training and support, beekeeping can serve as a steady and rewarding addition to their farming activities.

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BLUE TECH FRONTIERS: AQUA TECH PARKS AND THE FUTURE OF INDIAN FISHERIES

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Abstract

India's fisheries and aquaculture sector is rapidly evolving through the integration of advanced Blue Tech solutions and the rise of innovative infrastructure such as Aqua Tech Parks. These specialized hubs are transforming traditional fish farming by introducing cutting-edge technologies, fostering research, and providing essential training and incubation opportunities for startups. The article explores the pivotal role of Aqua Tech Parks in boosting productivity, ensuring environmental sustainability, and strengthening the blue economy. Highlighting milestones such as India's first Aqua Tech Park in Assam and similar initiatives across Andhra Pradesh and Tamil Nadu, the article showcases how these parks are setting new benchmarks for sustainable aquaculture. With a spotlight on selective breeding, hatchery innovations, and the emergence of promising Blue Tech startups, the piece outlines the future-ready approach India is adopting—balancing economic growth with responsible stewardship of aquatic resources.

Keywords: Blue Tech, AquaTech Parks, Indian Fisheries, Aquaculture Innovation, Sustainable Aquaculture.

Introduction

India's fisheries and aquaculture sector is undergoing a transformative shift, powered by cutting-edge technologies, sustainability-focused innovations and the growing vision of a robust blue economy. At the heart of this evolution lies the emergence of Aqua Tech Parks - dedicated hubs designed to modernize fish farming practices through research, training and infrastructure support. These parks are not only boosting productivity and efficiency but also serving as models

for environmentally responsible and economically viable aquaculture. As they expand across the country, Aqua Tech Parks are laying the foundation for a future-ready fisheries sector - one that balances growth with ecological harmony and livelihoods with innovation. Aquatic Park, located along the Berkeley shoreline is a popular spot for relaxation and recreation. A notable feature is the series of small "creeks" flowing into the lake along its eastern side. These creeks, however, are not natural; they were formed by redirecting storm drains during the park's development. These drains lead directly into the lake and may carry pollutants, raising concerns about water quality. Monitoring this is especially important for people engaging in water sports like sailing and water skiing. The issue is more pressing this year due to unusually heavy rainfall in Berkeley, which may cause more pollutants to reach the lake. This could happen through blocked drainage systems, leakage from aging tanks, or damage to pipes caused by shifting ground Northeast Today, (2025)

Introduction Blue Tech

Blue Tech refers to technological solutions designed for water, oceans, and aquatic resources. In aquaculture and fisheries, Blue Tech blends artificial intelligence, biotechnology, digital platforms, IoT, robotics, and renewable energy- enabling smarter, more sustainable marine and freshwater food systems. The tribune (2025)

Fig : 1 Aqua Tech Park

Blue Tech Innovations in India

- AI-driven aquaculture management
- Drones for fish monitoring and transport

- Underwater robotics for farm inspection
- IoT water quality sensing
- Biofloc and recirculating aquaculture systems
- Clean, solar-powered boats
- Digital platforms connecting producers and markets

The Rise of Aqua Tech Parks:

Assam's Milestone: India's First Aqua Tech Park

Opened in July 2025 in Sonapur, Assam, India's inaugural Aqua Tech Park showcases how cutting-edge infrastructure is transforming fish farming. The park features state-of-the-art technologies such as:

- Aquaponics (integrated fish and plant cultivation)
- Biofloc (microbe-based water treatment to improve fish health)
- Selective breeding and hatchery innovations
- Training centers for farmers and entrepreneurs
- Incubators for Blue Tech startup

Between 2019 and 2024, Assam successfully doubled its fish production, becoming the fourth-largest fish producer in India. This growth has significantly improved livelihoods and created new employment opportunities, especially for youth. Assam's success now serves as a model for other states to replicate. Northeast Today, (2025)

The Importance of Blue Tech and Aqua Tech Parks

India, the world's second-largest fish producer, supports the livelihoods of over 16 million people through fisheries. The use of modern technologies like IoT, robotics, Big Data, and sensors can greatly enhance productivity and resource efficiency. Aqua Tech Parks play a key role by serving as knowledge hubs, demonstration centers, and incubators that promote innovative solutions and sustainable business models. The economics times (2025)

Aqua Tech Parks offer multiple benefits to the aquaculture sector, including higher yields, lower costs, environmental sustainability, and improved export potential. Here's a breakdown:

Increased yields and reduced input costs for farmers

By integrating advanced technologies and scientific methods, farmers can cultivate more fish in less time while utilizing fewer resources like feed, water, and energy. This results in higher profits and enhanced farm productivity.

Lower environmental impact through efficient resource management

Aqua Tech Parks encourage sustainable aquaculture practices that reduce waste, prevent water contamination, and optimize the use of resources. This supports the protection of local ecosystems and promotes long-term environmental sustainability.

Enhanced quality and traceability for export markets

Utilizing modern monitoring systems and digital tracking, farmers can maintain consistent product quality and document the entire production cycle. This ensures better food safety and increases the competitiveness of Indian fish products in global markets.

Flagship Technologies and Initiatives

The Indian government has launched multiple initiatives to enhance the fisheries and aquaculture sector. These programs aim to increase production, upgrade infrastructure, and foster digital innovation. Key schemes include: The times of India (2024)

- The PMMSY (Pradhan Mantri Matsya Sampada Yojana) seeks to modernize the fisheries industry by boosting fish production, strengthening value chains, improving livelihoods, and promoting sustainable practices. It provides financial support and infrastructure development for both inland and marine fisheries.
- The Fisheries and Aquaculture Infrastructure Development Fund (FIDF) offers long-term loans to develop and upgrade critical fisheries infrastructure, including fish landing centers, cold storage facilities, processing units, and hatcheries. This fund helps establish a strong supply chain from catch to consumer.
- The National Fisheries Development Platform (NFDP) is a digital initiative designed to integrate various services and databases, enhancing transparency, efficiency, and ease of access for stakeholders. It facilitates real-time data sharing, online registrations, and improved governance within the fisheries sector.

Disruptive Trends in Aquaculture

The adoption of innovative technologies is significantly transforming India's fisheries and aquaculture sector in several ways:

1. Drones for Live Fish Transport: Drones are being piloted to transport live fish in remote or difficult-to-access regions, enhancing logistics and reducing transportation time and fish mortality.

2. Satellite and AI-based Systems: These technologies are improving the safety of fishers by providing real-time monitoring and alerts, while also enabling precise mapping and management of aquatic resources, leading to better resource utilization and conservation.
3. Digital Registration and Monitoring: Digital tools streamline the registration of aquaculture activities and continuously monitor operations, boosting transparency, ensuring compliance with regulations, and enhancing overall safety.
4. Eco-friendly Fish Farming Methods: Advanced systems such as biofloc technology and recirculating aquaculture systems (RAS) support sustainable fish farming by conserving water, minimizing pollution, and improving the efficiency and environmental footprint of aquaculture practices. The times of India (2024)

Startup Ecosystem and Industry Momentum:

Notable Blue Tech Startups

Aqua Connect

AquaConnect uses artificial intelligence and satellite data to help fish and shrimp farmers make informed decisions. Their digital platform offers real-time farm insights, improving productivity, disease prediction, and market access.

Reel Data AI

This company specializes in precision aquaculture by using AI to optimize fish feeding. Their system monitors fish behavior and adjusts feed amounts in real time, reducing waste, lowering costs, and supporting healthy fish growth.

Sea6 Energy

Sea6 Energy focuses on developing biofuels and bioplastics from seaweed. Their innovations provide sustainable alternatives to fossil fuels and contribute to both environmental conservation and the circular economy.

NAVALT Solar Boats

NavAlt designs and manufactures solar-powered boats that offer clean, emission-free mobility on water. These boats reduce dependence on diesel and are ideal for eco-friendly transport in coastal and inland waterways.

Clear Bot

Clearbot builds autonomous boats equipped to collect plastic waste from water bodies. These AI- powered vessels contribute to marine cleanliness by identifying and removing floating

debris efficiently and safely. The economics times (2025)

Challenges and the Road Ahead

India's aquaculture sector faces several key challenges. Traditional fishers often struggle to access capital and reach larger markets, limiting their growth opportunities. There are significant gaps in technology adoption across different regions, especially in rural and remote areas where awareness and infrastructure are lacking. Climate change poses another major barrier, highlighting the need for resilient and adaptive technologies to protect livelihoods. Additionally, the sector suffers from weak market linkages and insufficient cold chain infrastructure, resulting in post-harvest losses and reduced profitability**.**

The future of India's aquaculture lies in innovation, collaboration, and scaling up sustainable practices. One key direction is the nationwide expansion of Aqua Tech Parks, which will serve as demonstration and training centers to promote modern techniques among fishers and entrepreneurs. There will also be a broader adoption of AI, IoT, and digital platforms to enhance farm management, productivity, and traceability. The sector is expected to place greater emphasis on export-oriented, value-added seafood, boosting global competitiveness. Finally, stronger collaboration between government bodies, academic institutions, startups, and international partners will drive research, investment, and shared growth in the blue economy.

Table 1: Key Blue Economy Innovation Hubs in India

State	Project Name	Key Feature	Status	Year
Assam	Aqua Tech Park	Biofloc, aquaponics, Tech Training	Inaugurated	2025
Andhra Pradesh	Integrated Aqua Park	Value chain integration startup Focus	Under development	2024
Tamil Nadu	Fish Tank (Incubator)	Startup and Student Innovation	Ongoing	2025

The Vision for a Blue Tech Future:

India's push toward Blue Tech frontiers, embodied in its network of Aqua Tech Parks, promises a fisheries sector that is robust, innovative, and sustainable. With the right investments, digital inclusion, and entrepreneurial energy, India stands poised to lead a 21st-century marine revolution—ensuring food security, generating green jobs, and safeguarding aquatic ecosystems for generations to come.

Conclusion

India stands at the cusp of a revolution in its fisheries and aquaculture sector- one driven by bold ideas, sustainable technologies, and a commitment to empowering communities. The emergence of Aqua Tech Parks is more than just a modern upgrade to traditional fish farming. It represents a paradigm shift- where innovation meets conservation, and traditional livelihoods are transformed into thriving, tech-enabled enterprises.

By integrating cutting-edge technologies such as AI, IoT, biofloc, and aquaponics, these parks are setting new standards for productivity, efficiency, and environmental responsibility. More importantly, they're offering real opportunities for India's rural youth, entrepreneurs, and fishing communities to build resilient futures in the face of climate change and global food challenges.

The success of Assam's Aqua Tech Park is just the beginning. As similar initiatives take root across Andhra Pradesh, Tamil Nadu, and beyond, India has a chance to become a global leader in sustainable aquaculture and Blue Tech innovation. With coordinated policies, private sector participation, and grassroots engagement, the country can unlock the vast potential of its aquatic resources-feeding its population, fueling its economy, and preserving its waters for future generations.

The tide is turning. The future of Indian fisheries lies at the intersection of tradition and technology, and Aqua Tech Parks are the vessels steering that transformation toward a brighter, bluer tomorrow.

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APPLICATION OF UV SPECTROSCOPY IN AGRICULTURE

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Introduction to UV Spectroscopy

Spectroscopy is a method used to study how **materials interact with light** and other forms of energy. It measures how much light a substance absorbs, passes through, or gives off, depending on the light's wavelength. It can also study how particles like electrons and ions behave when they collide with other particles. Spectroscopy is a precise and non-destructive tool, commonly used in many areas of science for analysis.

Ultraviolet-visible (UV-VIS) spectroscopy focuses on light in the **ultraviolet (100–380 nm) and visible (380–750 nm)** ranges. This technique looks at how much of this light is absorbed by a substance. UV-Vis spectroscopy is used in finding internal constituents of agri-food products and soil analysis

Fig.1 UV Vis spectrophotometer

UV spectroscopy is a scientific method that involves analyzing how different substances interact with ultraviolet light. Each compound absorbs UV rays in its unique way, and by examining these patterns, we can determine what is present in a sample. This approach is particularly valuable in agriculture for studying plants, soil and water without causing any damage to the samples.

Understanding Soil through UV Light

Soil quality plays a vital role in successful farming. UV spectroscopy enables quick detection of elements like **essential nutrients (Nitrate, Phosphate), soil enzymes, organic carbon and contaminants.** This helps farmers understand soil condition accurately, which is crucial for making informed choices about fertilizers and land management practices.

UV-Vis helps detect the **amount of nitrate (NO_3^-)** in soil, which is a key nutrient for plant growth. Monitoring nitrates helps avoid over-fertilization, which can harm both plants and the environment. **Intensity of yellow colour** is measured using UV-Vis Spectroscopy. Intensity of yellow colour is proportional to the amount of nitrate content in soil.

Urease activity is often measured by detecting the **ammonia** released, using reagents that produce a colour change which is then measured by UV-Vis spectroscopy.

UV-Vis can estimate the amount of **organic matter** (like decomposed plants and animals) in soil by detecting certain light-absorbing compounds such as humic substances. Measure the **absorbance at 465 nm and 665 nm** using a UV-Vis spectrophotometer.

- **465 nm**: absorbance of fulvic acids-Dark brown to black (lower molecular weight)
- **665 nm**: absorbance of humic acids -Yellow to light brown (higher molecular weight).

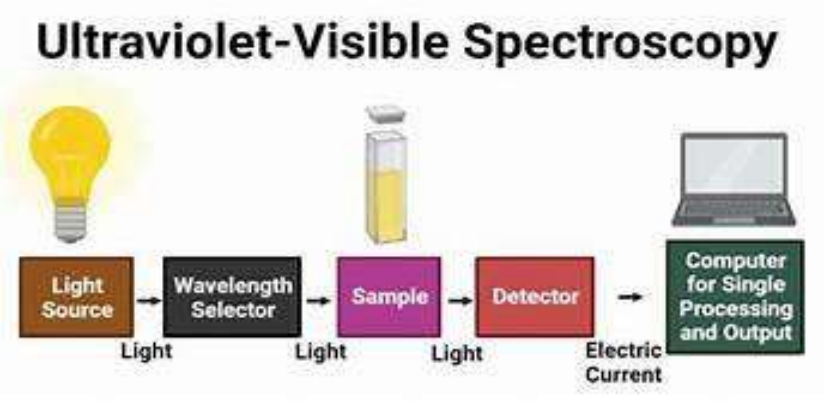

Fig.2 Block diagram of UV-Vis Spectrophotometer

Monitoring Plant Health Non-Invasively

Plants respond to environmental stress by changing their internal chemical makeup, which affects pigments like chlorophyll. These pigments reflect or absorb UV light differently when under stress. Chlorophyll absorbs strongly in the visible region (around 400–500 nm and 600–700 nm). When chlorophyll content decreases, the absorbance in these regions also decreases. Therefore, absorbance becomes lower during stress due to chlorophyll degradation. Using UV spectroscopy, farmers and researchers can spot early signs of disease or nutrient deficiency before visible symptoms appear.

Checking for Pesticide Residues Safely

Ensuring produce is safe to consume is essential. UV spectroscopy helps in the quick detection of chemical residues left by pesticides. Many of these chemicals have distinct UV absorption profiles, which makes the process reliable and useful for screening food products before distribution. Some of the pesticides which can be detected using UV-Vis Spectroscopy are listed below:

S.NO	PESTICIDE	CHEMICAL GROUP	DETECTION WAVELENGTH(nm)
1.	Carbaryl	Carbamate	280 nm
2.	Malathion	Organophosphate	220–240 nm
3.	Atrazine	Triazine	220–270 nm
4.	DDT	Organochlorine	236–280 nm

Analysing Irrigation Water Quality

UV spectroscopy is useful in monitoring irrigation water by detecting unwanted substances like nitrates and organic compounds. Measure absorbance of water at **220 nm and 275 nm**:

- **220 nm**: Nitrate peak absorbance
- **275 nm**: Organic matter peak absorbance

Regular testing ensures that water is suitable for crops and prevents long-term soil damage due to contaminated irrigation sources.

Field Applications with Portable UV Devices

Modern UV spectrometers are now compact and user-friendly, enabling their use directly on farms. These portable devices provide immediate insights into various factors like nutrient levels or crop stress, supporting precision agriculture and timely interventions.

S.NO	DEVICE NAME	APPLICATION
1.	SCiO	Pocket-sized spectrometer; analyzes crop health, nutrients, and moisture
2.	FieldSpec HandHeld 2	Measures reflectance in visible to near-infrared; used for chlorophyll and stress detection.
3.	MicroNIR™ OnSite-W	Handheld NIR/UV device for seeds, grains, and plant nutrient testing.
4.	Ocean ST Series	Miniature UV-Vis spectrometers for custom field applications (e.g., nitrate in water).
5.	Lab-on-a-Drone	Drones with UV-Vis sensors for aerial crop health monitoring.

Fig.3 Ocean ST Series -Miniature UV-Vis Spectrometer

Benefits and Challenges of Using UV Tools

The advantages of UV spectroscopy include its speed, non-invasive nature, and cost-effectiveness. However, challenges exist, such as equipment calibration and interpreting results accurately in complex field conditions. Nonetheless, it remains a promising tool in modern farming.

Conclusion

UV spectroscopy is being integrated with advanced technologies like AI and IoT to revolutionize agriculture. From drone-based UV sensors to automated crop monitoring systems,

the future holds exciting possibilities for efficient, sustainable farming practices. UV spectroscopy is emerging as a powerful tool in agriculture, offering farmers and Scientists innovative ways to manage crops, soil, and food safety. As more portable and smart devices become available, this technique is expected to become even more widespread in everyday agricultural practices.

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CRISPR/CAS9 – A GENOME EDITING TOOL: EMERGING TREND AND FUTURE PATHWAYS IN IMPROVEMENT OF VEGETABLE CROPS

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Abstract

In recent years, there has been a notable surge in research aimed at enhancing vegetable crop production and quality, driven by advancements in genome-editing technologies. Tools like CRISPR/Cas9 have enabled precise genetic modifications, leading to improvements in traits such as disease resistance, stress tolerance, nutritional content, and yield in various horticultural crops. CRISPR/cas9 is a rapidly evolving bio-technological tool creating a revolutionary impact by making the genome editing more precise, efficient and economical; substantially advancing vegetable crop enhancement. This article explores the transformative applications of CRISPR-Cas9 in enhancing traits such as disease resistance, abiotic stress tolerance, yield, and nutritional quality in vegetables. Notable advancements include the development of virus-resistant cucumber varieties through targeted gene knockouts and the enhancement of lycopene content in tomatoes via multiplex genome editing techniques. The integration of artificial intelligence with CRISPR technologies is accelerating the identification of target genes and optimizing editing strategies, thereby expediting the breeding process. Despite these advancements, challenges such as off-target effects, delivery mechanisms, and regulatory hurdles persist. Future pathways involve refining genome editing tools, developing transgene-free edited plants to alleviate regulatory concerns, and fostering public engagement to ensure the sustainable adoption of CRISPR-Cas9 technologies in vegetable crop improvement. By addressing these challenges,

CRISPR-Cas9 holds the potential to contribute significantly to global food security and sustainable agriculture.

Keywords: CRISPR/Cas9, genome-editing technology, precise, efficient, economical, off-target effects, global food security, sustainable agriculture.

Introduction

Fruit and vegetable crops are essential for balancing our daily diet because they are low in calories but high in vitamins and minerals. The diversity and nutritional worth of horticulture goods are declining, despite an increase in availability. The low genetic variety of horticultural crops brought about by domestication and breeding, as well as reproductive barriers that prevent genetic introgression from wild relatives, can be partly blamed for these declines. As a result, the development of genetic resources with a variety of desirable traits will be extremely valuable for enhancing agricultural products (Janick J *et al*.,2004), (Khoury CK *et al*., 2014). Humans started modifying crops by introducing new features from crossable relatives thousands of years ago. The transfer of advantageous genetic variants was the main objective. The differences were only produced naturally or spontaneously as recently as the 1930s. Breeders subsequently found how to create mutants using radiation or chemical mutagens. Crop productivity and quality have grown dramatically as a result of both natural and induced mutations.

However, getting acceptable materials for crop improvement has proven to be difficult and time consuming due to the rarity and randomness of these alterations (Oladosu Y *et al*., 2016), (Ahloowalia BS *et al*., 2001). DNA sequence-specific modification has developed into a potent tool as molecular biology has advanced so quickly. In 1987, many animal scientists developed homologous recombination-based gene-targeting technologies (HR). In addition to HR, somatic cells have another mechanism for DSB repair known as the error-prone nonhomologous end-joining (NHEJ) pathway, which can result in alterations due to minor deletions or insertions at break sites. Mega nucleases (MNs), zinc finger nucleases (ZFNs), transcription activator-like effector nucleases (TALENs), clustered regularly interspaced short palindromic repeats (CRISPR)/CRISPR-associated 9 (Cas9), and CRISPR from *Prevotella* and *Francisella* 1 (CRISPR/Cpf1) are the types of engineered endonucleases that researchers have used to introduce site-specific. In several biological systems, these designed endonucleases have made genome editing possible (Puchta H *et al*., 1993), (Voytas DF *et al*.,2013), (Zhu C *et al*.,

2017), (Zhang H *et al*., 2017). Finally, the use of genome editing in horticulture crops has rapidly expanded with the development of CRISPR/Cas9.

CRISPR/cas9 – HISTORY

The name CRISPR (Clustered Regularly Interspaced Short Palindromic Repeat) refers to the unique organization of short, partially repeated DNA sequences found in the genomes of prokaryotes. CRISPR and its associated protein (Cas-9) is a method of adaptive immunity in prokaryotes to defend themselves against viruses or bacteriophages (Hille F, Charpentier E., 2015). Japanese scientist Ishino and his team accidentally found unusual repetitive palindromic DNA sequences interrupted by spacers in *Escherichia coli* while analysing a gene for alkaline phosphatase first discovered CRISPR in 1987. However, they did not ascertain its biological function. In 1990, Francisco Mojica identifies similar sequences in other prokaryotes and he named CRISPR, yet the functions of these sequences were a mystery (Ishino Y *et al*., 2018). Later on in 2007, a CRISPR was experimentally conferred as a key element in the adaptive immune system of prokaryotes against viruses.

During the adaptation process, bacterial cells become immunized by the insertion of short fragments of viral DNA (spacers) into a genomic region called the CRISPR array. Hence, spacers serve as a genetic memory of previous viral infections (Ibrahim AU *et al*., 2019). The CRISPR defence mechanism protects bacteria from repeated viral attacks via three basic stages: adaptation (spacer acquisition), crRNA synthesis (expression), and target interference. CRISPR loci are an array of short repeated sequences found in chromosomal or plasmid DNA of prokaryotes. Cas gene is usually found adjacent to CRISPR that codes for nuclease protein (Cas protein) responsible to destroy or cleave viral nucleic acid (Rath D *et al*., 2015).

ADVANCEMENT OF CRISPR/cas9 OVER ZFN AND TALENS

Before the discovery of CRISPR/Cas-9, scientists were relied on two gene-editing techniques using restriction enzymes, zinc finger nucleases (ZFN) and Transcription activator-like effector nucleases (TALENs) (Gaj T *et al*., 2016). ZFN has a zinc finger DNA binding domain used to bind a specific target DNA sequence and a restriction endonuclease domain used to cleave the DNA at the target site. TALENs are also composed of DNA binding domain and restriction domain like ZFN but their DNA binding domain has more potential target sequence than the ZFN gene-editing tool. In both cases, the difficulty of protein engineering, being expensive, and time-consuming were the major challenges for researchers and manufacturers

(Gaj T *et al*., 2016, 2013). The development of a reliable and efficient method of a gene-editing tool in living cells has been a longstanding goal for biomedical researchers. After figuring out the CRISPR mechanism in prokaryotes, scientists understood that it could have beneficial use in humans, plants, and other microbes. It was in 2012 that Doudna, J, and Charpentier, E discovered CRISPR/Cas-9 could be used to edit any desired DNA by just providing the right template. Since then, CRISPR/Cas-9 becomes the most effective, efficient, and accurate method of genome editing tool in all living cells and utilized in many applied disciplines.

COMPONENTS OF CRISPR/cas9

Guide RNA (gRNA) and CRISPR associated (Cas-9) proteins are the two essential components in CRISPR/Cas-9 system. The Cas-9 protein, the first Cas protein used in genome editing was extracted from Streptococcus pyogenes (SpCas-9). It is a large (1368 amino acids) multi-domain DNA endonuclease responsible for cleaving the target DNA to form a double stranded break and is called a genetic scissor (Mei Y *et al*., 2016). Cas-9 consists of two regions, called the recognition (REC) lobe and the nuclease (NUC) lobe. The REC lobe consists of REC1 and REC2 domains responsible for binding guide RNA, whereas the NUC lobe is composed of RuvC, HNH, and Protospacer Adjacent Motif (PAM) interacting domains. The RuvC and HNH domains are used to cut each single-stranded DNA, while PAM interacting domain confers PAM specificity and is responsible for initiating binding to target DNA (Nishimasu H *et al*., 2017). Guide RNA is made up of two parts, CRISPR RNA (crRNA) and trans-activating CRISPR RNA (tracrRNA). The crRNA is an 18–20 base pair in length that specifies the target DNA by pairing with the target sequence, whereas tracrRNA is a long stretch of loops that serve as a binding scaffold for Cas-9 nuclease.

MECHANISM OF CRISPR/cas9 GENOME EDITING

The mechanism of CRISPR/Cas-9 genome editing can be generally divided into three steps: recognition, cleavage, and repair (Shao M *et al*., 2016). The designed sgRNA directs Cas-9 and recognizes the target sequence in the gene of interest through its 5′crRNA complementary base pair component. The Cas-9 protein remains inactive in the absence of sgRNA. The Cas-9 nuclease makes double-stranded breaks (DSBs) at a site 3 base pair upstream to PAM (Ceasar SA *et al*., 2016). PAM sequence is a short (2–5 base-pair length) conserved DNA sequence downstream to the cut site and its size varies depending on the bacterial species. The most commonly used nuclease in the genome-editing tool, Cas-9 protein recognizes the PAM

sequence at 5′-NGG-3′ (N can be any nucleotide base). Once Cas-9 has found a target site with the appropriate PAM, it triggers local DNA melting followed by the formation of RNA-DNA hybrid, but the mechanism of how Cas-9 enzyme melts target DNA sequence was not clearly understood yet. Then, the Cas-9 protein is activated for DNA cleavage. HNH domain cleaves the complementary strand, while the RuvC domain cleaves the non-complementary strand of target DNA to produce predominantly blunt-ended DSBs. Finally, the DSB is repaired by the host cellular machinery (Mei Y *et al*., 2016) (Jiang F *et al*., 2017).

REPAIR MECHANISMS OF DOUBLE STRAND BREAK

Non-homologous end joining (NHEJ), and homology directed repair (HDR) pathways are the two mechanisms to repair DSBs created by Cas-9 protein in CRISPR/Cas-9 mechanism (Liu M *et al*., 2019). NHEJ facilitates the repair of DSBs by joining DNA fragments through an enzymatic process in the absence of exogenous homologous DNA and is active in all phases of the cell cycle. It is the predominant and efficient cellular repair mechanism that is most active in the cells, but it is an error-prone mechanism that may result in small random insertion or deletion (indels) at the cleavage site leading to the generation of frameshift mutation or premature stop codon. HDR is highly precise and requires the use of a homologous DNA template. It is most active in the late S and G2 phases of the cell cycle. In CRISPR-gene editing, HDR requires a large amount of donor (exogenous) DNA templates containing a sequence of interest. HDR executes the precise gene insertion or replacement by adding a donor DNA template with sequence homology at the predicted DSB site (Liu M *et al*., 2019) (Yang H *et al*., 2020).

APPLICATION OF CRISPR/cas9 IN IMPROVEMENT OF VEGETABLE CROPS

TOMATO

Tomatoes are the vegetable species that have gathered the most research using the CRISPR/Cas9 system, either due to the crop's economic relevance or the simplicity of Agrobacterium-based genetic modification. Given consumer desire and processing needs, parthenocarpy in tomatoes may be a desirable characteristic (Tian S *et al.*, 2017). The CRISPR/Cas9 system can be utilized as a breeding technique to create parthenocarpic tomato plants (Nekrasov V *et al*.,2013). On the tomato variety Micro-Tom, five different sgRNAs were initially used to introduce mutations into SlIAA9, a crucial gene that regulates parthenocarpy. The commercial cultivar Ailsa Craig was altered using the sgRNA2 since it had the highest mutation efficiency. The authors also discovered bi-allelic and homozygous mutations in Micro-

Tom and Ailsa Craig T0 regenerated plants. As anticipated, fruit without seeds was produced by regenerated mutants. Similar to this, plants with a homozygous or biallelic mutation in the SlAGAMOUS-LIKE 6 (SlAGL6) gene in the tomato produced predominantly parthenocarpic fruits and a few lowseeded fruits after the SlAGL6 gene was altered (containing up to 10 seeds) (Xiong X *et al*., 2019). The HDR repair pathway was used to replace the recessive 'alc' allele of Alcobaca (SlALC) to create tomatoes with a long shelf life. It was then able to create an alc homozygous mutant that was free of foreign DNA and had better storage capabilities than wild-type controls. Lycopene improvement and fruit quality features are two more traits that were effectively changed to enhance the tomato (Xu ZS *et al*., 2017). The tomato fruit's ripening process was sped up by editing the genes for APETALA2a (AP2a), NON-RIPENING (NOR), and FRUITFUL (FUL1/TDR4 and FUL2/MBP7). Edited plants naturally ripened their fruit earlier, and this study revealed new information on how FUL1 and FUL2 function during fruit ripening. In SELF PRUNING 5G-edited CRISPR/Cas9 tomato plants, several intriguing traits including day-neutral, improved compact determinate growth, rapid flower output, and early yield were also noted (Murovec J *et al*., 2018). The acetolactate synthase (ALS) gene was also altered to produce herbicide resistance in tomatoes and potatoes.

POTATO

To produce outstanding potatoes, it is essential to reduce the quantity of steroidal glycoalkaloids (SGAs), such as solanine and chaconine, in tubers. These compounds may have an unfavourable impact on human health when present in high concentrations. As a result, the potato steroid 16-hydroxylase (St16DOX) involved in SGA production was targeted using the CRISPR/Cas9 system (Soyk S et al., 2017). *NPH3/RPT2-LIKE1* protein (*NRL1*) interacts with effector Pi02860 of *Phytophthora infestans* and creates a protein complex, promoting the proteasome-mediated degradation of the guanine nucleotide exchange factor SWAP70. SWAP70, as a positive regulator, enhances cell death triggered by the perception of the *P. infestans* pathogen-associated molecular pattern (PAMP) INF1. Using a clustered regularly interspaced short palindrome repeats (CRISPR)/CRISPR-associated protein 9 (Cas9) system, a construct was made to introduce four guide RNAs into the potato cultivar Agria. A CRISPR/Cas9-engineered potato line with a four-allelic knockout of the StNRL1 gene exhibited approximately 90% reduction in gene expression, leading to enhanced resistance against Phytophthora infestans (Mohsen Nourozi *et al*.,). Tetraploid cv. Desisree developed through

induced mutation in StPPO2 gene through CRISPR/cas 9 results in lower amount of polyphenol activity (PPO) in tuber with consequent reduction in browning.

WATERMELONS

A single point mutation was created in the acetolactate synthase (ALS) gene, a crucial enzyme for the manufacture of the branched-chain amino acids valine, leucine, and isoleucine, to produce herbicide-resistant watermelon plants.

CABBAGE

In 2015, CRISPR/Cas9 technology was first applied to cabbage DH1012 by targeting BolC.GA4.a, an ortholog of AtGA4, which is involved in gibberellin biosynthesis. Cas9 driven by a constitutive promoter from Cassava Vein Mosaic Virus, and two sgRNAs targeting the first exon of BolC.GA4.a was constructed in the binary vector. Eighty independent transgenic lines were generated by Agrobacterium-mediated transformation. Through restriction digest/PCR assay, two lines with indels at the target sites were identified out of 20 T0 lines. Additionally, two lines with expected dwarf phenotype were identified through phenotypic screen. Homozygous mutants for BolC.GA4.a showed a dwarf phenotype, and the pod valve margin was affected (Lawrenson *et al*. 2015).

CHINESE CABBAGE

Recently, genome editing was achieved in Chinese cabbage using CRISPR/Cas9 technology. Researchers developed a DNA-free method for the site-directed mutagenesis of endogenous genes using RNPs in protoplasts (Murovec *et al.*, 2018). Meanwhile, BraFLCs, homologs of AtFLC, were targeted using CRISPR/Cas9. Braflc2flc3 double knockout lines were obtained, and the simultaneous mutations were stably inherited in the T1 generation. The edited plants showed an early-flowering phenotype that was independent of vernalization (Jeong *et al*. 2019), indicating that CRISPR can be used for molecular breeding.

RAPESEED

Rapeseed (*Brassica napus* L.), an allopolyploid crop formed by hybridization between *B. oleracea* and *B. rapa*, is one of the most important oil crops worldwide. In 2017, CRISPR/Cas9 was applied to rapeseed. Two BnALC homeologs were targeted knockout by a CRISPR/Cas9 construct containing only one target sequence, and T1 plants with four alc mutant alleles were obtained. All the mutations were faithfully transmitted to the T2 progeny. Siliques (5–6 cm long)

from the alc mutants were more shatter-resistant than same sized siliques of the cultivar (Braatz *et al*., 2017).

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ROLE OF SOCIAL AND SOLITARY BEES IN POLLINATION

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Introduction

Social bees are insects that live in highly organized, cooperative colonies. These colonies typically include a queen, who lays eggs, and numerous workers, who perform various tasks like foraging, nest building, and caring for the young. Examples of social bees include honey bees, bumble bees, and stingless bees. Social bees typically build nests in cavities. Honeybees prefer hollow trees or man-made hives, creating combs out of wax for storing honey, pollen, and brood. Bumblebees often nest below ground in abandoned rodent burrows or holes in trees. Stingless bees in tropical areas have also co-evolved with flowering plants and are crucial pollinators.

Characteristics of social bees

- Colony structure: A single queen, workers, and drones (in some species)
- Division of labor: Different individuals perform different tasks (e.g., foraging, caring for young, defending the colony)
- Communication: Use complex dances, pheromones, and other signals to communicate
- Cooperative behavior: Work together for the benefit of the colony.
- Social immunity: Colonies have mechanisms to prevent disease spread and protect individual bees.

The commonly found social bees are

1. Honey bees (*Apis mellifera, Apis cerana indica , Apis florea , Apis dorsata*):

Live in colonies with a single queen, thousands of worker bees (females), and drones (males).

2. Bumble bees (*Bombus* spp.): Live in colonies with a single queen and hundreds of worker bees (females).

3. Stingless bees (Meliponini): Live in colonies with a single queen and thousands of worker bees (females).

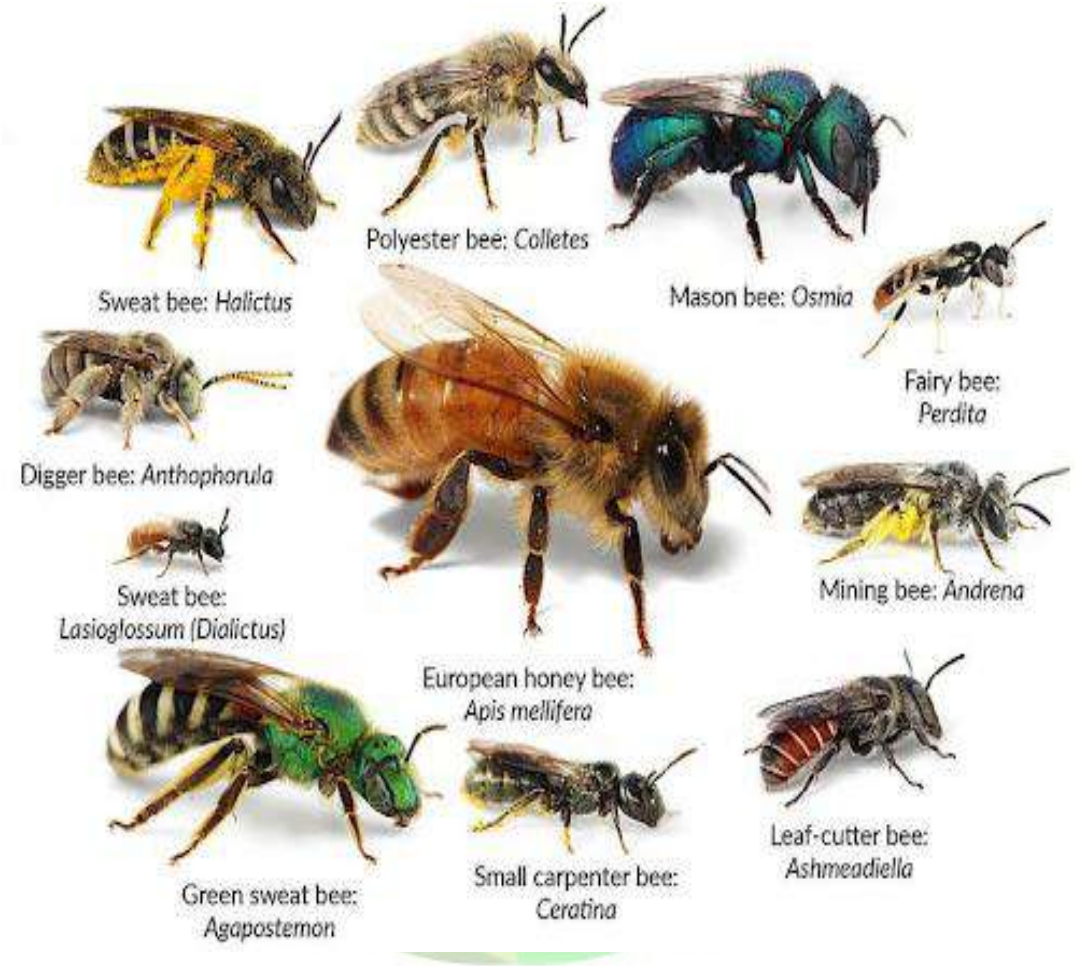
Honey bees

Honey bees include the well-known European honey bee (*Apis mellifera*) as well as 8 other species of Apis that are native to Europe, Asia, and Africa. These bees usually nest above ground, often inside hollow trees. They construct vertical wax combs with individual hexagonal cells for storing honey and rearing brood. Each hive is "ruled" by a single queen whose only job is to lay eggs. Workers are adult females — daughters of the queen. They perform all housekeeping chores within the hive, search for nectar and pollen, produce wax and honey, feed the young and protect the hive against enemies. Adult workers live for about six weeks (during the summer) but queens may last for several years. During cold winters, the bees cluster together, feeding on stored food reserves and sharing their body heat.

Social caste is determined mostly by the diet an individual bee receives during larval development. Normally, workers feed their larvae royal jelly (a nutrient-rich glandular secretion) for the first few days and then switch to a less-nutritious diet of bee bread (a mixture of honey and pollen). Larvae destined to become queens, however, are reared in special (larger) brood cells and fed a diet of royal jelly throughout the entire duration of larval development. Males (drones) develop from unfertilized eggs. Their only function is to mate with virgin queens.

A queen controls the social organization within her colony by means of a pheromone secreted from her mandibular glands. Workers lick this pheromone from the queen's body and pass it to nestmates during the exchange of food (trophallaxis). Queen pheromone maintains tranquility within the hive and inhibits ovarian development among workers. When the queen dies (or fails to perform adequately), she is replaced by a new queen reared from within the hive. Each colony, therefore, has the potential to be perennial, that is, to endure beyond the lifespan of the founding queen and her workers. Mature, healthy colonies may grow to include as many as 80,000 workers. However, before they reach this size, most large bee hives will "reproduce" by

swarming. This is a process of colony division in which an established queen leaves (absconds) with a large group of workers to establish a new nest site, while a young queen and the remaining workers stay behind to occupy the old nest site.



Honey bees use a variety of signals to communicate with nestmates. An aggregation pheromone produced by Nasanov's gland (located near the tip of the abdomen) is used to attract nestmates and to mark a source of nectar or water. An alarm pheromone is released from mandibular glands when the colony is threatened. Scout bees who find a good nectar supply will recruit foragers by passing out samples of the nectar and "dancing" on the comb to indicate distance and direction to the source.

Honey bees in pollination

- Honey bees (Apis mellifera) play a crucial role in pollination, contributing to:
- Pollination of crops: Honey bees pollinate many agricultural crops, including fruits, vegetables, nuts, and seeds, such as almonds, apples, blueberries, and avocados.

- Seed production: Honey bees facilitate seed production in many plant species, ensuring genetic diversity and plant reproduction.
- Ecosystem health: Honey bees pollinate flowers and plants in natural ecosystems, maintaining biodiversity and ecosystem balance.
- Food security: One-third of the food we eat, including many staple crops, relies on honey bee pollination.
- 5.Economic importance: Honey bee pollination services are valued at over $200 billion annually, globally.

Honey bees' pollination efficiency is due to:

- Furry bodies: Collect and transport pollen effectively
- Specialized structures: Honey bees have basket-like corbiculae on their legs for pollen collection
- Social behavior: Communicate and coordinate pollination efforts through complex dances and pheromones
- High visitation rates: Visit multiple flowers in a single trip, facilitating cross-pollination.

Bumble bees (Bombus spp.) play a vital role in pollination, contributing to:

About 300 species of eusocial bumble bees have been described worldwide but their distribution is almost entirely limited to temperate zones in the northern hemisphere. Colony structure is largely seasonal. Mated queens hibernate during the winter and emerge in early spring to build a small nest site containing a "honey pot" and several brood cells. After gathering a supply of nectar and filling her "honey pot", each queen lays a few eggs and "singlehandedly" rears her first brood — all daughters. When these offspring become adults, they remain unmated, stay with the queen, and serve as the first members of the colony's worker caste. Thereafter, the queen does very little except lay eggs while her workers perform all tasks related to gathering food, enlarging the nest, and caring for the young**.**

Bumble bee colonies have a relatively primitive social structure. They rarely contain more than few hundred workers and, other than size, there is usually little or no physical distinction between a queen and her workers. Caste determination appears to be based on food supply and the queen's aggressive behavior. Bumble bees have no system for communicating information

about food location to other members of the hive. Novice bees evidently learn to forage efficiently through a process of "trial and error".

- Pollination of crops: Bumble bees pollinate many agricultural crops, including tomatoes, blueberries, cucumbers, and squash.
- Seed production: Bumble bees facilitate seed production in many plant species, ensuring genetic diversity and plant reproduction.
- Ecosystem health: Bumble bees pollinate flowers and plants in natural ecosystems, maintaining biodiversity and ecosystem balance.
- Specialized pollination: Bumble bees are important pollinators of certain crops, like tomatoes, which require "buzz pollination" (vibrating pollen grains for release).
- Complementary pollination: Bumble bees often pollinate different plant species than honey bees, ensuring broader pollination coverage.

Bumble bees' pollination efficiency is due to:

- Large size and strength: Allow them to fly in cooler temperatures and vibrate pollen grains for release.
- Long tongues: Enable them to reach nectar deep within flowers.
- Furry bodies: Collect and transport pollen effectively.
- Solitary behavior: Focus on foraging and pollination without distractions.

Blue banded bees

Cuckoo bees

Carpenter Bees

Leaf cutter bees

Bumble bees

Mason Bees

Sweat Bees

Digger Bees

Stingless Bees

Italian bees

Indian Bees

Little bees

Rock Bees

Black Indian Bees

Stingless bees (Meliponini) role in pollination:

- Pollination of crops:Stingless bees pollinate various crops, such as coffee, cocoa, mangoes, and avocados.
- Seed production: They facilitate seed production in many plant species
- Tropical and subtropical pollination: They are important pollinators in tropical and subtropical regions, where they are often more abundant than honey bees.
- Specialized pollination: Some stingless bee species are specialized pollinators of specific plants, like the fig tree (Ficus spp.).

Stingless bees

Stingless bees include about 300 eusocial species that are mostly tropical or sub-tropical in distribution. They are called "stingless bees" because the sting is reduced in size and rarely used for defense. These bees often nest in hollow trees or rock crevices. They collect nectar and pollen from flowers and store honey in large egg-shaped pots made of cerumen, a mixture of beeswax and plant resin. The honeypots are usually arranged in an irregular perimeter around a central brood comb that is constructed in horizontal layers.

Most species of stingless bees are relatively small (less than 1 cm in length) and live in colonies that contain one queen and 50-1000 workers. A few species, however, are as large as European honey bees and may have over 40,000 workers living together. Both queens and workers develop from fertilized eggs, but queen larvae have larger brood cells and receive more food than worker larvae. Males (drones) develop from unfertilized eggs (often laid by unmated workers). Most of the stingless bees form perennial colonies with the ability to replace the queen when she dies. Large colonies may divide by swarming, but workers usually build and provision a new nest before it will be occupied by a young queen and a group of workers from the old nest.

There is a wide range of social organization and communication among the species of stingless bees. Some produce low-frequency sound vibrations to alert nestmates to a new nectar source, others mark vegetation with an odor trail for recruits to follow, and still others enlist a group of foragers and guide them back to the food source. In tropical habitats, stingless bees have co-evolved with flowering plants since the Cretaceous period and these bees are now essential as pollinators for many native plants. Conservation efforts are needed to protect both the plants and the bees from habitat destruction.

Stingless bees' pollination efficiency is due to:

Stingless bees are efficient pollinators due to several factors, including their ability to forage effectively in various conditions, their tolerance of high temperatures, and their lack of aggression towards humans. They are also less susceptible to diseases and parasites that can affect other pollinating insects like honeybees. Furthermore, stingless bees are valuable for crop pollination because they visit a wide range of crops and don't pose a risk to natural habitats by escaping and becoming invasive.

- High visitation rates: They visit multiple flowers in a single trip, facilitating cross-pollination.
- Furry bodies: Collect and transport pollen effectively.
- Social behavior: Communicate and coordinate pollination efforts through complex dances and pheromones.
- Adaptation to native plants: Stingless bees have co-evolved with native plants, making them effective pollinators in their ecosystems.

Solitary bees

Among the pollinators not all are social honeybees, the fact is that nearly 85 percent of bee pollinators are solitary in nature. Though solitary bees are inferior when compared to social honey bees in terms of pollinating efficiency, their importance in the ecological system is uncompromised one. The resemblance of solitary bees is not like honey bees instead they more look like a wasp, female live solitarily in that it will mate independently and makes the nest of about 10 brood cells either in the dry soil or the dead wood logs. It forages on several crop plants for its young one, thereby it pollinates the crops. The collected nourishment is stuffed into each cell of the brood then it lays egg on it (mass provisioning). Nowadays because of anthropogenic activities many of the solitary bees losing their natural habitat and their population rate is keep on decreasing and readiness of nesting place looks to be a regulating factor for these bees. Indeed, farmers in different region started providing suitable habitat provisioning for the solitary bees where the efficiency of pollination by honey bees are found to be a limiting factor.

Major Solitary Bees Solitary Bees are mainly residing among the nine families of order Hymenoptera,

- Colleitdae / Membrane bees
- Andrenidae / Digger bees

- Halticidae / Sweat bees
- Megachilidae / Leaf cutter and Mason bees
- Anthophoridae / Carpenter and Minor bees
- Meltittidae
- Oxaeidae
- Fiedellidae
- Orchid bees

Characteristics

1. Small to medium size: Solitary bees are often smaller than social bees.
2. Metallic colors: Many solitary bees have metallic green, blue, or copper colors.
3. Important pollinators: Solitary bees are efficient pollinators of many crops and wildflowers.
4. Diverse species: There are over 4,000 species of solitary bees, making them one of the most diverse bee groups.

Carpenter bees (*Xylocopa* spp.)

Carpenter bees are important pollinators, particularly of plants with poricidal anthers that require buzz pollination. They are also known to forage on a wide variety of plants and can be active under low light conditions. While their tendency to bore into wood can be a nuisance, they play a beneficial role in plant reproduction.

Carpenter Bees and Pollination:

Buzz Pollination:

Carpenter bees are known for their buzz pollination technique, where they vibrate their flight muscles to dislodge pollen from flowers with poricidal anthers. This method is crucial for the reproduction of many plants, including some economically important crops.

Generalist Foragers:

They are generalist foragers, meaning they collect pollen and nectar from a wide range of plant species, making them valuable pollinators in diverse ecosystems. Carpenter bees are relatively tolerant of high temperatures and can be active under low light conditions, making them effective pollinators in different environments.

Examples of Pollination:They have been observed as efficient pollinators of passionflowers, blueberries, greenhouse tomatoes, and greenhouse melons.

Nectar Robbing:

In some cases, carpenter bees may engage in nectar robbing by creating holes at the base of flowers to access nectar without pollinating them, particularly on flowers with long, tubular corollas

- Pollination of crops: Carpenter bees pollinate various crops, such as:
    - Fruits (e.g., blueberries, strawberries)
    - Vegetables (e.g., tomatoes, peppers)
    - Nuts (e.g., almonds, walnuts)
- Efficient pollinators: Carpenter bees are efficient pollinators due to their:
    - Large size and strength, allowing them to fly in cooler temperatures
    - Long tongues, enabling them to reach nectar deep within flowers
    - Furry bodies, collecting and transporting pollen effectively
- Specialized pollination: Some carpenter bee species are specialized pollinators of specific plants, like the passionflower (*Passiflora* spp.).

Leafcutter bees (Megachilidae) :

Leafcutter bees are valuable pollinators, particularly known for their role in alfalfa and other crop pollination, as well as their unique nesting behavior of cutting leaf pieces to build their nests. They are solitary bees, meaning each female constructs her own nest, unlike social bees like honeybees.

Leafcutter bees and their role in pollination

Pollination

- Leafcutter bees are efficient pollinators, often used commercially for crops like alfalfa, blueberries, and sunflowers.
- They are particularly effective pollinators because they carry pollen on their fuzzy abdomens, allowing them to transfer pollen quickly and efficiently.
- One leafcutter bee can pollinate as effectively as twenty honeybees, especially in greenhouse settings where they thrive in higher temperatures.

Nesting Behavior

- Leafcutter bees are named for their habit of cutting circular pieces from leaves to use in nest construction.

- They typically nest in pre-existing cavities like hollow stems, dead wood, or man-made structures.
- The leaf pieces are used to create individual brood cells within the nest.

Types of Leafcutter Bees

Several species exist, with *Megachile rotundata* (alfalfa leafcutter bee) being one of the most well-known for its commercial use in alfalfa seed production, Cucumbers , Melons , Pumpkins and Squash

Benefits of using leafcutter bees for pollination

They are gentle and non-aggressive, making them safe to work around. They can be managed and placed in areas where pollination is needed, such as during the bloom period of specific crops. They are effective pollinators in various environments, including greenhouses.

Conservation

Leafcutter bees are important native insects, and their nesting preferences (such as using soft wood or plant stems) can sometimes lead to concerns, but they are generally beneficial pollinators. Efforts to conserve leafcutter bees often involve providing suitable nesting materials and habitats.

Leafcutter bees are efficient pollinators due to their

- Relatively large size and strength
- Long tongues, enabling them to reach nectar deep within flowers
- Furry bodies, collecting and transporting pollen effectively
- Unique behavior: Leafcutter bees are known for their distinctive behavior of cutting pieces of leaves to use in constructing their nests, which can lead to increased pollination efficiency.

Mason bees (Osmia spp.)

Mason bees are highly effective pollinators, particularly for fruit trees, due to their efficient pollen-carrying behavior and ability to forage in cooler, less predictable weather. They are solitary bees that can be managed in artificial nests to enhance pollination in orchards and other agricultural settings.

Efficient Pollen Transfer

Unlike honey bees that carry pollen on their legs, mason bees (specifically those in the family Megachilidae, which includes Osmia species) have pollen-collecting hairs (scopa) on

their abdomens. This allows them to carry more pollen and deposit it more readily on flowers, increasing pollination rates.

Early Bloom Foragers

Mason bees are often the first pollinators to emerge in the spring, making them ideal for pollinating early blooming fruit trees like cherries and apples. They can forage in cooler temperatures and even light rain, unlike many other pollinators, making them valuable when weather conditions are less than ideal.

Solitary Nature

While they can be gregarious and nest near each other, mason bees are solitary, meaning each female is responsible for building her own nest and provisioning it with food for her offspring.

Nesting Preferences

Mason bees utilize pre-existing cavities for nesting, such as hollow reeds, beetle-excavated holes in wood, or man-made nesting blocks

Pollination of crops: Mason bees pollinate various crops, such as:

Apples, Berries (e.g., blueberries, strawberries), Cherries, Peaches and Pears

Specialized pollination: Some mason bee species are specialized pollinators of specific plants, like the apple (*Malus domestica*).

Blue banded bees (*Amegilla* sp)

Blue banded bees are solitary creatures and commonly seen on flowers and play a greater role in crop pollination. Many Solanaceous plants such as, eggplant, capsicum and tomatoes depend on bee pollination for increasing their productivity . Blue banded bees are potential pollinators of greenhouse tomatoes. Tomato yield was increased in greenhouses due to the pollination activity of *Amegilla chlorocyanea*. The huge, plumpy, juicy grubs of Dawson's bees (*Amegilla dawsoni*) were used as food for the local aborigines of Australia.

Blue banded bees collect nectar or pollen or both. They are usually more attracted towards the yellow coloured flowers followed by white and purple flowers. Among the various plant families, Fabaceae, Solanaceae, Cucurbitaeae, Compositae and Bignoniaceae appear to be predominantly preferred for foraging by these bees. Both male and female bees are floral visitors. Female bees collect both pollen and nectar while male bees sip nectar alone from the flowers.

They frequently hover above and around the flowers before landing on them. They fly very fast and quickly visit many flowers per minute. They are often seen darting around the flowers. They commence their foraging activity around 6.00 am and stop foraging at 6.30 pm and their flight activity continue all throughout the day. However, they show intense activity from 7.00 am to 9.00 am. The bee visitation is generally more on days following the rains. A single bee visits numerous flowers during each foraging trip. Pollen foraging is taken up by the mother bee after brood cell construction. Bees after pollen foraging return to the nest with their scopa on hind legs loaded with pollen.

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ASSIMILATION OF MINERAL NUTRIENTS –BIOLOGICAL NITROGEN FIXATION

Article ID: AG-V05-I08-06

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Introduction

Nitrogen fixation is a process in which nitrogen (N_2) in the atmosphere is converted into ammonia (NH_3). For centuries together it was a well-known fact that by growing leguminous crops the reduced fertility of land can be increased again. The reason for this increase in fertility was not known for long. Later on, it was found that the fertility of the soil increases due to some bacteria which are found in root nodules of leguminous crops and soil and these bacteria are capable of fixing atmospheric nitrogen. Nitrogen fixation can be defined as the phenomenon of conversion of free nitrogen in to nitrogenous salts to make it available for absorption by plants.

Biological Nitrogen Fixation:

Conversion of molecular nitrogen (N_2) of the atmosphere into inorganic nitrogenous compounds such as nitrates or **ammonia** is called as nitrogen fixation. When this nitrogen fixation occurs through the agency of some living organisms, the process is called as biological nitrogen fixation in which atmospheric nitrogen is converted into ammonia.

An estimated 190 **x** 10^{12} gm per year of N_2 is fixed by natural processes (both non-biological and biological). Of this, biological nitrogen fixation accounts for about 90%. Non-biological nitrogen fixation (by lightening (8%) and UV radiations (2%) contributes about 10% of the total N_2 fixed by natural processes.

The Haber-Bosch industrial chemical process fix ammonia production, which uses elevated temperatures (about 200°C) and high pressures (about 200 atmospheres) accounts for an estimated 80 **x** 10^{12} gm per year of N_2 converted to ammonia on global basis and seldom meets

agricultural demand. Significance of biological nitrogen fixation is quite obvious because it is carried out at ambient temperatures and one atmosphere by a variety of living bacteria, cyanobacteria (blue-green algae) and symbiotic bacteria.

Nitrogen Fixing Organisms

Not all the organisms have capacity to fix molecular nitrogen (N_2) of the atmosphere. Only certain prokaryotic micro organisms such as some free living bacteria, cyanobacteria (blue green algae) and some of the prokaryoric micro-organisms in symbiotic association with other plants (mostly legumes) can fix atmospheric nitrogen. They can be grouped as follows.

A**. Free Living**

1. Autotrophic

(a) **Aerobic** e.g., some cyanobacteria (blue-green algae). All those blue-**green algae which** can fix atmospheric nitrogen, usually contain heterocysts such as *Nostoc, Anabaena,* etc. But all the heterocysts bearing blue-**green algae may not** be atm nitrogen fixers. A few non-heterocystous blue-green algae such **as** *Gloeotheca are also* known to fix atm N_2.

(b) **Anaerobic** *e g ,* certain bacteria such **as** *Chromatium* **and** *Rhodospirillum.*

2. **Heterotrophic**

(a) Aerobic e.g., certain bacteria such as *Azotobacter, Azospirillum,*

*(b)***Facultative** *e.g.,* certain bacteria such as *Bacillus* **and** *Klebsiella.*

(c) Anaerobic e.g., certain bacteria such as *Clostridium* **and** *Methanococcus.*

B. Symbiotic

(a) Root Nodules of Leguminous Plants

Various types of bacteria called rhizobia associated with root nodules of legumes can fix atm. N_2. None of these two partners ***i.e.,*** bacterium or legume alone can fix atm. N_2. Rhizobia are aerobic bacteria that belong to different genera such as *Rhizobium, Azorhizobium, Bradyrhizobium, Photorhizobium* and *Sinorhizobium.*

A number of different species and varieties of these rhizobia infect specific leguminous host plants. Among these, *Rhizobium leguminosarum* is most common and well known. Different species of this bacterium specifically infect a number of leguminous crop plants such as clovers *(Trifolium),* pea *(Pisum **sativum)*** and bean ***(Phaseolus).*** Rhizobia remain free-living in the soil before infecting their respective host plant.

(b) Root Nodules of *Parasponia*

Rhizobial symbiont of this host plant is *Bradyrhizobium* sp

(c) Actinorhizal plants

Many species of as many as 23 genera of non-leguminous angiosperms which are all dicot and woody (trees or shrubs) and belonging to 8 different families, bear root nodules that can fix atmospheric nitrogen ***e.g.,*** *Myrica*, *Casuarina*. etc. In all these plants, the bacterial symbiont is a filamentous soil-bacterium belonging to the genus *Frankia* of Actinomycetes.

(d) **Other Symbiotic Associations**

A herbaceous plant, *Gunnera* and water fern *Azolla* form symbiotic association with blue-green algae *Nostoc* and *Anabaena* respectively which can fix atm. N_2. Association of some blue-green algae with fungi in some lichens is also known to fix atmospheric nitrogen.

Symbiotic nitrogen fixation is carried out by bacteria frequently found in the root nodules of leguminous plants. The most common bacterium is *Rhizobium*. It has two types of strains, (a) fast growers that include *R. leguminosarum* or *Bacillus radicicola*, *R, faciolii*, and (b) slow growers that include *R japonicum* and *R. lupinei* . *Rhizobia* are commonly found in the soil of crop field where bacteria and plant both specifically affect each other's growth.

Nodule formation:

The development of nodule is rather a complicated process. In the initial stage, host cells have to recognise the correct strain of symbiotic bacteria. A critical specificity is involved in the association of various species of root nodule bacteria and leguminous plants. This step is controlled by specific proteins found in a host cell called lectin. These lectins interact selectively with microbial cell carbohydrates (or glycoproteins) found in the capsule of bacteria and serve as determinants of recognition or host specificity. This interaction induces some responses in host plants and may result in exclusion or inclusion of bacteria in the host cell. Thus, lectins are the key proteins involved in the Rhizobium-legume symbiotic association and in the process calcium plays a critical role in modifying the ability of root to absorb rhizobia.

Nodule formation is initiated by the infection of root hair by free living rhizobia. Since these bacteria cannot digest cellulose it enters the root hair from the tip region where cellulose is nearly absent. The process of nodule formation is very peculiar. Leguminous plants release tryptophan in the soil which is absorbed by *Rhizobium* and is metabolised to produce IAA (indole acetic acid). The Rhizobia produce another characteristic substance called root hair curling factor

that causes deformation **and** twisting of root hairs. The root hair gets penetrated by a large number of rhizobia which collectively convert into an infection thread lined by cellulose which is provided *by* the host cell. The infection thread intrudes, settles and liberates its contents in a cortical cell which is usually a polyploid (tetraploid). The rhizobia are liberated either individually or in small groups enclosed by a membrane. The cells of bacteria enlarge, assume pleomorphic shape and are called bacteroids. These bacteroids stimulate ploypoid cell to undergo repeated divisions. These also include the surrounding cells (diploid cells) to divide which ultimately from the cortex of a nodule.

The nodule contains a pink coloured ***leghaemoglobin*** pigment which like true haemoglobin combines with oxygen and CO_2 and gets readily oxidised into brown form with a trivalent iron. The development of leghaemoglobin and nitrogen fixing capacity are outcome of symbiotic interaction, since individually neither leguminous plats produce leghaemoglobin nor bacteria carry out nitrogen fixation. The symbiotic relationship is so essential that in the absence of ***Rhizobium*** and combined nitrogen in soil leguminous plants do not grow. There are two views about the location of leghaemoglobin that it is either located in the space between bacteroids and the membrane enclosing them or is present outside the membrane and in the host cytoplasm.

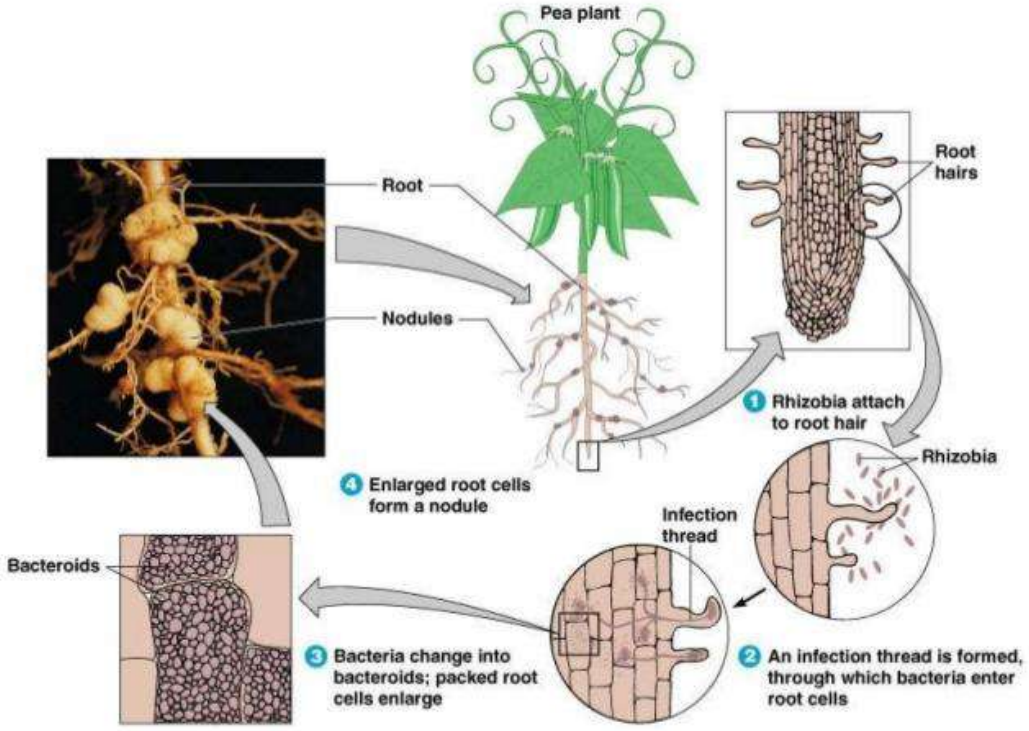


Fig: 1.FORMATION OF A ROOT NODULE

Mechanism of nitrogen fixation:

The Nitrogenase Enzyme Complex Fixes N_2

It has now been fully accepted that the process of nitrogen fixation, whether in symbiotic or asymbiotic forms, involves reduction of atmospheric nitrogen to ammonia (NH_3) by the enzyme ***nitrogenase***.

Biological nitrogen fixation, like industrial nitrogen fixation, produces ammonia from molecular nitrogen. The overall reaction is

$$N_2 + 8\ H^+ + 8\ e^- + 16\ ATP + 16\ H_2O \longrightarrow 2\ NH_3 + H_2 + 16\ ADP + 16\ P_i$$

Note that the reduction of N_2 to 2 NH_3, a six-electron transfer, is coupled to the reduction of two protons to evolve H_2. The nitrogenase enzyme complex catalyzes this reaction.

The nitrogenase enzyme complex can be separated into two components—the Fe protein and the MoFe protein neither of which has catalytic activity by itself. The Fe protein is the smaller of the two components and has two identical subunits of 30 to 72 kDa each, depending on the organism. Each subunit contains an iron–sulfur cluster (4 Fe and 4 S_2^-) that participates in the redox reactions involved in the conversion of N_2 to NH_3.

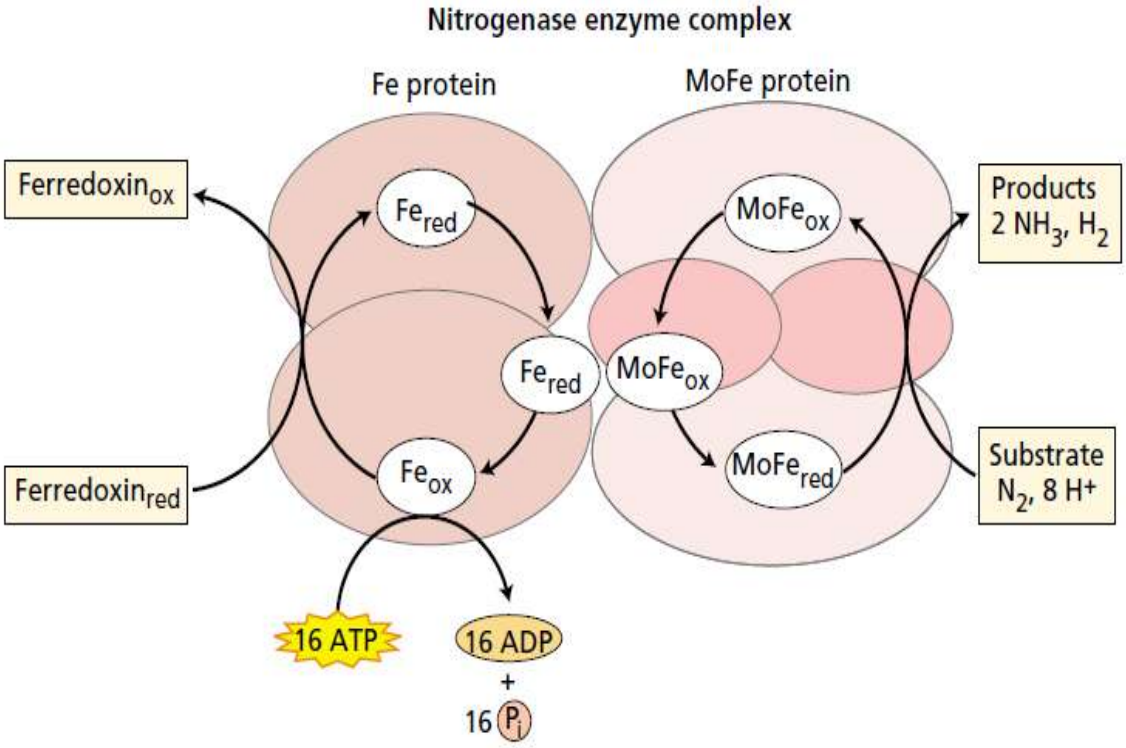
The MoFe protein has four subunits, with a total molecular mass of 180 to 235 kDa, depending on the species. Each subunit has two Mo–Fe–S clusters. The MoFe protein is also inactivated by oxygen, with a half-decay time in air of 10 minutes.

In the overall nitrogen reduction reaction, ferredoxin serves as an electron donor to the Fe protein, which in turn hydrolyzes ATP and reduces the MoFe protein. The MoFe protein then can reduce numerous substrates, although under natural conditions it reacts only with N_2 and H^+. One of the reactions catalyzed by nitrogenase, the reduction of acetylene to ethylene, is used in estimating nitrogenase activity.

The Fe-protein component of *nitrogenase* it smaller than its other component and is an Fe-S protein which is extremity sensitive to O, and is irreveritibly inactivated by it. This Fe-S protein is a dimer of two similar peptide chains each with a molecular mass of 30-72 kDa (depending upon the micro-organism). This dimer contains four Fe atoms and four S atoms.

The MoFe protein component of *nitrogenase* is larger of the two components and consists of different peptide chains which are associated as a mixed tetramer with a total molecular mass of 180 - 235 k Dalton (depending upon the micro-organism). This component is also sensitive to O_2.

Because *nitrogenase* enzyme complex is sensitive to O_2 biological nitrogen fixation requires anaerobic conditions. If the nitrogen fixing organism is anaerobic than there is no such problem. But, even when organism is aerobic, nitrogen fixation occurs only when conditions are made to maintain very low level of O_2, or almost anaerobic conditions prevail inside them around the enzyme *nitrogenease*.



Direct measurement of nitrogen fixation is done by mass spectroscopy. However, for comparative studies reduction of acetylene can be measured rather easily by gas chromatography method.

The electrons are transferred from reduced ferredoxin or flavodoxin or other effective reducing agents to Fe-protein component which gets reduced. From reduced Fe-protein, the electrons are given to MoFe-protein component which in turn gets reduced and is accompanied by hydrolysis of ATP into ADP and inorganic phosphate (Pi). Two Mg^{++} and 2 ATP molecules are required per electron transferred during this process.

From reduced MoFe-protein, the electrons are finally transferred to molecular nitrogen (N_2) and 8 protons, so that two ammonia and one hydrogen molecule are produced.

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ANTICANCER PROPERTIES OF TURMERIC

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Abstract

Curcumin, a polyphenol derived from turmeric, has demonstrated potential anticancer properties in laboratory studies. Its mechanisms include anti-inflammatory effects, antioxidant activity, apoptosis induction, and inhibition of cell proliferation. Curcumin may enhance conventional cancer treatments and target cancer stem cells. Despite poor bioavailability, formulation strategies and ongoing research offer promise for its use in cancer prevention and therapy. This review highlights curcumin's potential as a safe, non-toxic, and cost-effective supplement in the fight against cancer.

Keyswords: Curcumin , Targeting of cancer stem cells (CSCs), MicroRNAs (miR), curcuminoids, Low-Density Lipoprotein (LDL), Reactive Oxygen Species (ROS).

Introduction

Cancer is a complex and multifaceted disease that involves the uncontrolled growth and spread of abnormal cells in the body.While conventional treatments like surgery, chemotherapy, and radiation therapy are standard, research is increasingly exploring the role of natural substances in supporting cancer therapy. The key ingredient in turmeric curcumin has shown potential anticancer properties in numerous studies. Numerous preclinical studies have demonstrated that curcumin can inhibit the growth of various types of cancer cells, Its anticancer activity is primarily attributed to its ability to regulate multiple cell signaling pathways involved in tumor initiation, progression, angiogenesis (formation of new blood vessels), and metastasis (spread of cancer). Curcumin exerts its effects by modulating molecular targets such as

transcription factors (e.g.NF-κB), enzymes (e.g.COX-2, MMPs), cytokines, and growth factors. It also promotes apoptosis (programmed cell death) in cancer cells without affecting normal healthy cell despite its low bioavailability when consumed orally, advances in drug delivery systems such as Nanoparticles, Liposomes and Curcumin analogs are being explored to enhance its effectiveness in clinical settings. Alternative therapies have long history of use in Curcumin treating different disorders. It was reported that curry has 2% Curcumin. In industrialized countries cancer is one of the major causes of mortality.

Cancer in India: A Growing Concern

One woman dies of cervical cancer every eight minutes in India. Over 700,000 new cancer cases are registered annually. According to the Indian Council of Medical Research (ICMR), about 556,400 deaths per year are cancer related. Cervical cancer is the second most common cancer in Indian women. An estimated 2.5 million people in India are living with cancer.

What is Curcumin?

Curcumin is a low molecular weight polyphenol derived from the rhizome of the *Curcuma longa* plant.It is the active yellow pigment in turmeric and has been used for centuries to treat inflammatory diseases in traditional medicine. Extensive research has revealed that curcuminoids (natural compounds in turmeric) can interact with multiple cell signaling pathways involved in cancer development.

Survival Signals

The survival signals are upregulated against anticancer therapy in order to regulate the proliferation and survival of cancerous cell. C.longa have the potential to inhivit the growth of squamous cell carcinoma of head and neck (SCCHN) xenograft tumors.

Anticancer Mechanisms of Curcumin

Curcumin exhibits several mechanisms that contribute to its anticancer activity:

1. Anti-inflammatory Effects

Chronic inflammation plays a significant role in cancer development. Curcumin inhibits **pro-inflammatory molecules** such as cytokines and enzymes like COX-2.Inhibits key inflammation pathways

2. Antioxidant Activity

Curcumin neutralizes reactive oxygen species (ROS), which can damage DNA and

promote cancer.Neutralizes free radicals.

3. Apoptosis Induction

Curcumin helps trigger **apoptosis** - a form of programmed cell death

4. Inhibition of Cell Proliferation

It slows down the uncontrolled division of cancer cells

5. Cardioprotective Effects

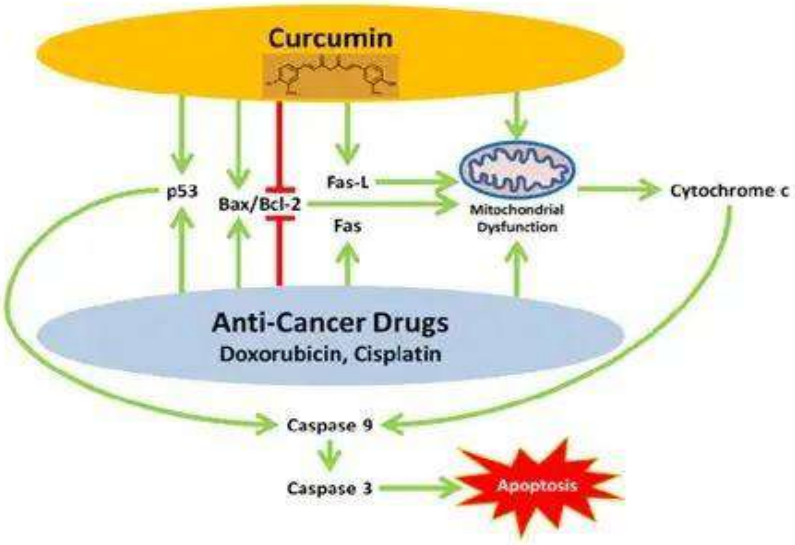
Reduces LDL cholesterol and triglyceride levels and also iimproves endothelial function.It has potential in preventing atherosclerosis.

Sensitization to Chemotherapy and Radiotherapy

Curcumin can enhance the effectiveness of conventional cancer treatments. Reduces drug resistance and improves treatment response (notably with drugs like doxorubicin, cisplatin, and paclitaxel).

Targeting of cancer stem cells (CSCs)

CSCs are important targets for the therapeutic strategy of cancer treatment becausr cancer renewal and treatment properties depend upon CSCs .Targeting of CSCs is a latest approach to control the relapse,recurrence and treatment failure of the cancer. It was found that CSCs could be targeted by curcumin and its analogs as chemo preventive agents.



Targeting of MicroRNAs (miR)

Limitations and Challenges of Curcumin

1. Poor bioavailability limits systemic effects when taken orally.

2. Requires formulation strategies (e.g., nanoparticles, liposomes, or piperine) for improved efficacy.
3. Most clinical trials are in early phases or use curcumin as an adjunct therapy

Clinical Evidence of curcumin

In a clinical study, patients with colorectal cancer were given up to 180 mg/day of curcumin for four months with no adverse side effects. Many ongoing studies continue to explore curcumin as a supportive therapy alongside conventional treatments.

Curcumin and Specific Cancers

Breast Cancer

Curcumin inhibits the Akt/mTOR signaling pathway, which is responsible for cell proliferation in breast cancer. This inhibition results in tumor growth suppression.

Skin Cancer

Skin cancers can be treated using turmeric since a long time in traditional medicine by applying the herbal preparation topically.

Brain Tumors

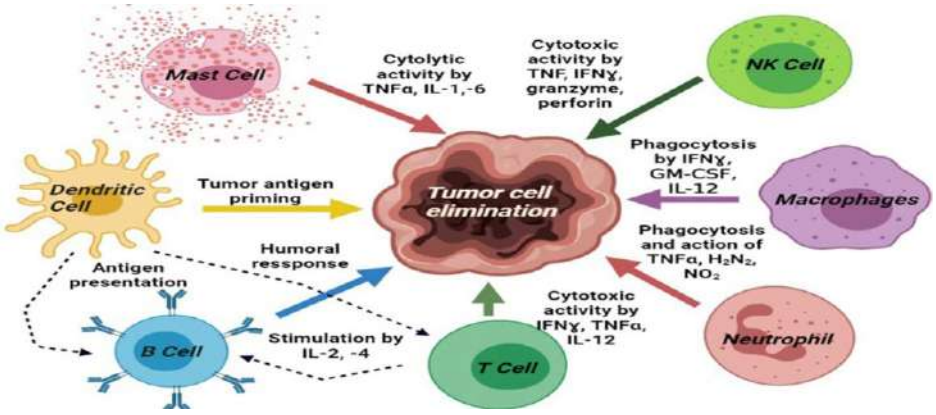
Brain tumors are among the most resistant cancers. Although curcumin has poor natural absorption, nanoparticle-based delivery methods have successfully improved its concentration in brain tissues, increasing its therapeutic effect.

Head and Neck Carcinogenesis treatment

These are mostly carcinomas of the squamous cell .*In vitro* and *in viv*o studies revealed that curcumin can treat head and neck cancers.

Ovarian Cancer

Curcumin alone or with docetaxel is used to treat ovarian cancers.



Conclusion

Turmeric active compound curcumin has shown promising anticancer properties in laboratory. From reducing inflammation to stopping cancer cell growth and enhancing the immune response, curcumin offers a natural way to support cancer prevention and treatment. With ongoing research and clinical trials, curcumin is increasingly being recognized as a safe, non-toxic, and cost-effective supplement that could complement conventional cancer therapies. In conclusion, curcumin represents a promising, multifaceted compound in the fight against cancer, offering hope for more natural and less harmful treatment options in the future.

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NUTRIENT STATUS, THERAPEUTIC, NON-THERAPEUTIC AND DIVERSIFIED USES OF COWPEA (*Vigna unguiculata*)

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Abstract

Cowpea also known as southern peas or black-eyed peas is a highly multipurpose and resilient crop with a long history of traditional uses across many cultures, particularly in Africa and Asia. Every part of the plant, from the seeds and pods to the leaves, has been traditionally utilized for food, animal feed and even in medicine and agriculture. It is a nutrient-dense legume that offers a range of therapeutic properties, attributed to its rich content of macronutrients, dietary fiber and a variety of bioactive phytochemicals. Usual consumption of cowpea has been associated to potential benefits in managing a number of chronic diseases.

Its nutrient profile is well-rounded, providing a significant amount of macronutrients, micronutrients and beneficial compounds. However, like many legumes, it also contains anti-nutritional factors that can be mitigated through proper processing.

Macronutrients

- **Protein:** Cowpea is an excellent source of plant-based protein, with content typically ranging from 23% to 32% of its dry weight. This makes it a valuable protein alternative for vegetarian. It is particularly rich in the essential amino acid lysine, which is often deficient in cereal grains like rice and maize. However, it is low in the sulfur-containing amino acids methionine and cysteine.
- **Carbohydrates:** Cowpea is a carbohydrate-rich food, containing about 50% to 67% carbohydrates. These include complex carbohydrates like starch and a significant amount

of dietary fiber (both soluble and insoluble), which promotes healthy digestion, helps regulate blood sugar and contributes to a feeling of fullness.

- **Fats:** Cowpea has a very low-fat content, typically less than 3%, making it a lean source of energy. The small amount of fat present includes essential fatty acids like linoleic and oleic acids.

Micronutrients (Vitamins and Minerals)

Cowpea is a excellent source of several essential minerals and vitamins.

- Vitamins: It is particularly rich in B vitamins, especially folate (B9), which is crucial for cell growth and is highly important for pregnant women to prevent birth defects. It also contains notable amounts of thiamin (B1), riboflavin (B2), niacin (B3) and vitamin B6. The leaves and green pods are also rich in provitamin A (beta-carotene) and vitamin C.
- **Minerals:** Cowpea is a valuable source of several key minerals, including:
  - **Iron:** Essential for blood production and preventing anemia.
  - Magnesium: Important for nerve function, muscle contraction and bone health.
  - Phosphorus: A key component of bones and teeth and vital for energy metabolism.
  - **Zinc:** Supports immune function and cellular growth.
  - **Calcium:** Crucial for bone and dental health.
  - **Potassium:** Helps regulate blood pressure and fluid balance.

Other Beneficial Compounds

- **Dietary Fiber:** The high fiber content in cowpea acts as a prebiotic, promoting the growth of beneficial gut bacteria, which can enhance digestive health and immunity.
- **Antioxidants and Phenolic Compounds:** Cowpea contains various antioxidant compounds, such as flavonoids and phenolic acids (e.g., ferulic acid and gallic acid), which helps to protect the body cells from damage caused by free radicals and may reduce the risk of chronic diseases.

Anti-Nutritional Factors

Cowpea, like other legumes, contains certain compounds that can interfere with nutrient absorption if not processed correctly. These include:

- **Phytates:** These can chelate minerals like iron, zinc and calcium, reducing their bioavailability.
- **Tannins:** These can affect protein digestibility and mineral absorption.

- Protease Inhibitors: Compounds like trypsin and chymotrypsin inhibitors can interfere with protein digestion.

Fortunately, traditional cooking and processing methods significantly reduce the levels of these anti-nutritional factors. Soaking, cooking, fermentation and germination are highly effective at breaking down these compounds, thereby improving the digestibility and overall nutrient bioavailability of cowpea.

Bioactive compounds

Cowpea contains a diverse range of volatile and non-volatile bio active compounds that contribute to its aroma, flavor, nutritional value and defense mechanisms. These compounds are found in various parts of the plant, including the flowers, leaves and seeds, and their composition can change depending on factors like processing, stress and plant variety.

Volatile Compounds

Volatile compounds are responsible for the aroma and "off-flavors" often associated with cowpea. These low-molecular-weight compounds are often produced from the breakdown of amino acids and fatty acids. The volatile compounds found in cowpea include:

- **Aldehydes:** These are a predominant class of volatile compounds in cowpea. Examples include hexanal, trans-2-hexenal, (Z)-4-heptenal, nonanal, and 2-nonenal. Hexanal and trans-2-hexenal are particularly noted for contributing to the green and beany aroma. This compound plays a role in plant defense mechanisms and is also used in flavorings and fragrances.
- **Alcohols and Ketones:** These can be a significant component of the volatile profile. Examples include 1-hexanol, 1-octen-3-ol, and 1-penten-3-one.
- **Aromatic Compounds:** Compounds like benzaldehyde, toluene and acetophenone have been identified, particularly in the floral volatiles, where they serve as cues for pollinators.
- **Terpenes:** Cowpea also contains monoterpenes and sesquiterpenes, which can be found in the leaves, flowers and seeds.

Function of Volatile Compounds:

- **Aroma and Flavor:** They are the primary contributors to the characteristic aroma of cowpea. While some contribute to desirable flavors, others like hexanal and 1-octen-3-ol can cause "off-flavors" described as beany, green, or rancid.

- **Plant-Insect Interactions:** Volatile compounds play a crucial role in the plant's defense against pests. Cowpea plants release specific volatile organic compounds (VOCs) that can deter herbivores or, conversely, attract the natural enemies of those herbivores. For example, some floral volatiles attract pollinators, while others, known as herbivore-induced plant volatiles (HIPVs), can repel pests like the legume pod borer.

Non-Volatile Compounds

Non-volatile compounds are responsible for many of the nutritional, anti-nutritional and sensory properties of cowpea, such as taste and texture. They include a wide range of primary and secondary metabolites.

- **Primary Metabolites:** Cowpea is an important source of essential nutrients.
  - **Proteins and Amino Acids:** It is a valuable source of protein and contains various amino acids like alanine, valine, serine, threonine and glycine.
  - **Carbohydrates:** Cowpea seeds contain sugars (e.g., sucrose, glucose, fructose) and complex carbohydrates like starch and dietary fiber.
  - **Lipids:** Although low in fat, cowpea contains fatty acids, including oleic, linoleic, palmitic and stearic acids.
- **Secondary Metabolites:** These compounds are often associated with the plant's defense and physiological responses.
  - **Phenolic Compounds:** These include flavonoids like kaempferol and quercetin, which have been linked to aphid resistance in certain cowpea varieties. Other phenolic compounds can contribute to bitter and astringent tastes.
  - **Alkaloids and Saponins:** These compounds are known to contribute to bitterness and have anti-nutritional properties, though they also serve a defensive role.
  - **Sugars and Osmolytes:** Under stress conditions like drought, cowpea plants can accumulate osmoregulatory molecules such as soluble sugars, proteins and proline to help them cope with water deficit.
  - **Anti-nutritional Factors:** Cowpea contains compounds that can interfere with nutrient absorption, such as tannins, phytic acid and enzyme inhibitors. Processing methods like cooking or germination can reduce the levels of these compounds.

Function of Non-Volatile Compounds:

- **Nutrition:** Non-volatile compounds form the core nutritional value of cowpea, providing

protein, carbohydrates and minerals.

- **Defense:** They are a key part of the plant's defense system. Phenolic compounds, for instance, are a chemical barrier against pests.
- **Sensory Properties:** They manipulate the texture and taste of cowpea. For example, some compounds contribute to bitterness or astringency, while others like sugars affect sweetness.
- **Stress Response:** Compounds like proline and soluble sugars help the plant adapt to environmental stresses like drought and salinity.

Therapeutic uses of Cowpea

1. Cardiovascular Health

Cowpea consumption is beneficial for heart health due to its low-fat and high-fiber content.

- Cholesterol Reduction: The high amount of soluble dietary fiber in cowpea can help to lower "bad" low-density lipoprotein (LDL) cholesterol levels by binding to cholesterol in the digestive tract and preventing its absorption.
- Blood Pressure Regulation: Cowpea is a good source of minerals like potassium and magnesium, which are essential for maintaining healthy blood pressure and proper heart muscle function.
- Antioxidants: The presence of flavonoids, phenolic acids and other antioxidants helps to reduce oxidative stress, which is a major contributor to cardiovascular disease.

2. Blood Sugar Management

Cowpea is an excellent food for individuals with diabetes or those at risk of developing it.

- Low Glycemic Index: Cowpea has a low glycemic index, means its carbohydrates are digested slowly. This results in a gradual rise in blood sugar levels, preventing the rapid spikes and crashes that can be dangerous for diabetics.
- **High Fiber and Protein:** The combined high content of dietary fiber and protein slows down the absorption of sugar into the bloodstream, helping to maintain stable blood glucose levels.
- **Enzyme Inhibition:** Some compounds in cowpea can inhibit the activity of carbohydrate-digesting enzymes, further contributing to a slower release of glucose.

3. Anti-inflammatory and Antioxidant Properties

The therapeutic properties of cowpea are largely due to its potent antioxidant and anti-inflammatory compounds, particularly concentrated in the seed coat of colored varieties.

- Polyphenols: Cowpea is rich in polyphenols, including flavonoids and phenolic acids. These compounds act as powerful antioxidants that neutralize harmful free radicals in the body, which can cause cell damage and lead to chronic inflammation and diseases like cancer.
- **Fatty Acids:** Research has shown that some polyunsaturated fatty acids found in cowpea, such as linoleic and linolenic acids, exhibit significant anti-inflammatory effects.

4. Digestive Health and Weight Management

Cowpea's composition makes it a great choice for promoting digestive health and aiding in weight control.

- **High Fiber Content:** The abundant dietary fiber, both soluble and insoluble, promotes regular bowel movements, prevents constipation and supports a healthy gut microbiome by acting as a prebiotic.
- **Satiety and Weight Loss:** The combination of protein and fiber provides a feeling of fullness and satiety, which can help reduce overall calorie intake and assist in weight management.

5. Potential Anti-Cancer and Anti-Microbial Effects

Initial research suggests that certain compounds in cowpea may have protective effects against some types of cancer and possess anti-microbial properties.

- **Antioxidant Effects:** The anti-inflammatory and antioxidant activities of cowpea polyphenols may play a role in inhibiting the growth of cancer cells, though more research is needed to fully understand these mechanisms.
- **Antimicrobial Peptides:** Cowpea proteins contain peptides that have shown antimicrobial, antiviral, and antifungal properties in laboratory studies.

Non therapeutic uses of Cowpea

1. Human Food and Culinary Uses

Cowpea is a critical food source, especially in developing regions, due to its high nutritional value, particularly its protein content. It is often referred to as "the meat of the poor" due to its affordability and nutritional value.

- **Dried Seeds:** The most common use is the consumption of mature, dried seeds. They are a staple in many traditional dishes, where they are boiled, stewed, or mashed. In West Africa, they are ground into a paste to make in style foods.
- **Fresh Vegetables:** Young, green pods and immature seeds are consumed as a fresh vegetable. They are often boiled or stir-fried, similar to green beans.
- **Cowpea Leaves:** The tender leaves are eaten as a leafy green vegetable in many parts of Africa and Asia. They are a good source of vitamins, minerals and protein. They are often used in soups, stews and relishes.
- **Flour and Other Products:** Dried cowpeas are milled into flour, which can be used as a gluten-free protein-rich additive in breads, snacks and complementary foods for infants.

2. Agricultural and Environmental Uses

Cowpea is an invaluable crop in sustainable farming systems due to its ability to improve soil health and resilience.

- **Nitrogen Fixation:** As a legume, cowpea forms a symbiotic relationship with nitrogen-fixing bacteria in its root nodules. This process enriches the soil by converting atmospheric nitrogen into a usable form for the plant, reducing the need for synthetic fertilizers.
- **Cover Crop and Green Manure:** Cowpea's rapid growth and broad leaves make it an excellent cover crop. It helps to prevent soil erosion, suppress weeds and retain soil moisture. When the plant is tilled back into the soil, it acts as a "green manure," providing organic matter and nutrients for subsequent crops.
- **Intercropping:** Cowpea is often planted in combination with cereal crops like maize and sorghum. This practice, known as intercropping, not only improves soil fertility for the companion crop but also provides an additional source of food and income for farmers.

3. Animal Feed and Forage

Cowpea is an important source of feed for livestock, particularly in arid regions where other forage is scarce.

- **Forage and Hay:** The entire cowpea plant, including the leaves and stems, is used as a high-quality forage for cattle, sheep and goats. It is either grazed directly or harvested and stored as hay or silage for use during the dry season.

- **Grain Feed:** The dried seeds are also used as a protein-rich supplement in livestock feed. Cowpea haulms (the leftover plant matter after harvesting the pods) are a crucial feed component in mixed crop-livestock farming systems.

4. Industrial and Emerging Uses

Beyond its traditional roles, research is exploring new applications for cowpea.

- **Food Processing:** Cowpea flour and isolated proteins are being used in the food industry for various applications, including the production of fortified foods, canned products and protein supplements. Its functional properties, such as water and oil binding, make it suitable for a variety of food formulations.
- **Material Science:** The functional proteins from cowpea are being researched for non-food applications, such as the development of new materials for UV-protective fabrics and the microencapsulation of vitamins.

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DIGITAL EXTENSION REVOLUTION: KVK OOTY'S YOUTUBE SUCCESS STORY TRANSFORMS AGRICULTURAL OUTREACH IN THE NILGIRIS

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Introduction

In an era where smartphones have become ubiquitous even in remote farming communities, agricultural extension services are undergoing a digital transformation. The ICAR-Krishi Vigyan Kendra (KVK), Tamil Nadu Agricultural University (TNAU), The Nilgiris, has embraced this change by launching their YouTube channel in August 2024, creating a new paradigm for technology dissemination and farmer education.

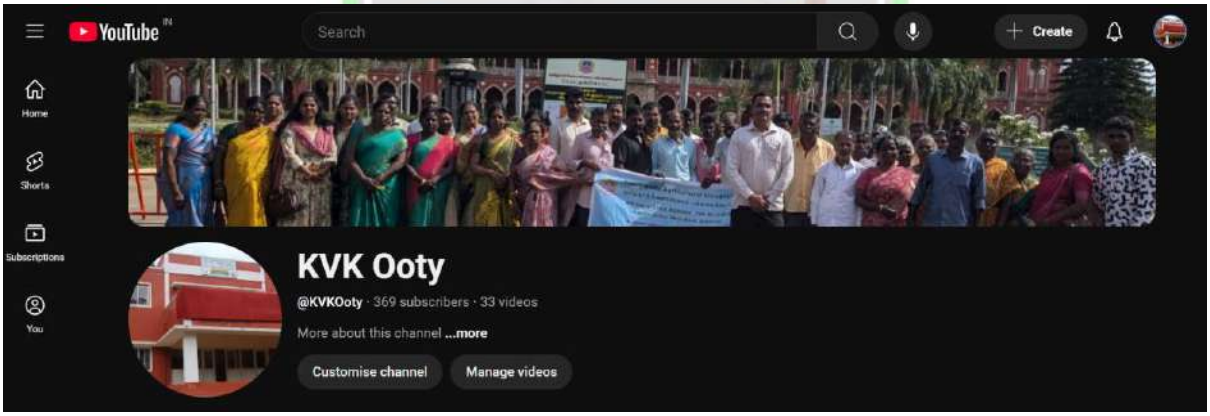

Image 1: Profile page of KVK Ooty Youtube Channel

The Numbers Tell a Compelling Story

Within less than a year of operation, the KVK Ooty YouTube channel has achieved remarkable milestones that underscore the appetite for digital agricultural content among farming communities. With 33 carefully curated videos uploaded, the channel has attracted 369 dedicated subscribers and garnered 1,489 views, accumulating an impressive 50.2 hours of watch time. These figures, while modest in the broader YouTube ecosystem, represent a significant

achievement in agricultural extension, where quality engagement often matters more than viral reach.

The channel's analytics reveal fascinating insights into farmer behavior and preferences. With 17,950 impressions and a healthy 7% click-through rate, the content is clearly resonating with its target audience. The average view duration of 2.02 minutes suggests viewers are genuinely engaging with the technical content rather than merely scrolling past. Perhaps most tellingly, the channel has reached 1,253 unique viewers, indicating a growing community of farmers actively seeking agricultural knowledge through digital platforms.

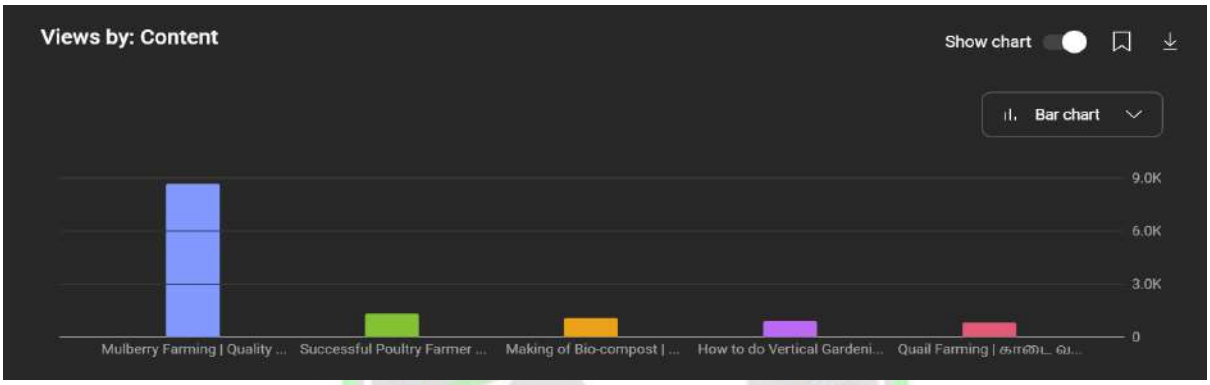

Image 2: Statistics of the views by content in KVK Ooty Youtube Channel.

Understanding the Digital-Native Farmer

The demographic data from KVK Ooty's channel provides valuable insights into modern agricultural extension. The primary audience falls within the 35-44 age group, representing experienced farmers who are established in their practices yet open to technological advancement. This demographic sweet spot is crucial for agricultural extension, as these farmers possess both the experience to understand complex agricultural concepts and the influence to drive adoption within their communities.

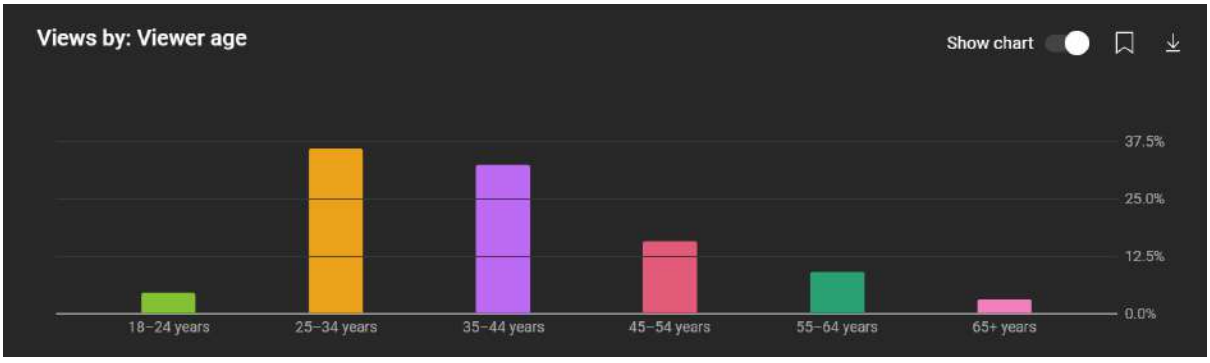

Image 3: Statistics of the views by viewers age in KVK Ooty Youtube Channel.

The overwhelming preference for mobile viewing, with 88.5% of users accessing content through smartphones, reinforces the importance of mobile-first content strategy in agricultural extension. This trend reflects the broader digitization of rural India, where mobile phones have become the primary gateway to information, entertainment, and education.

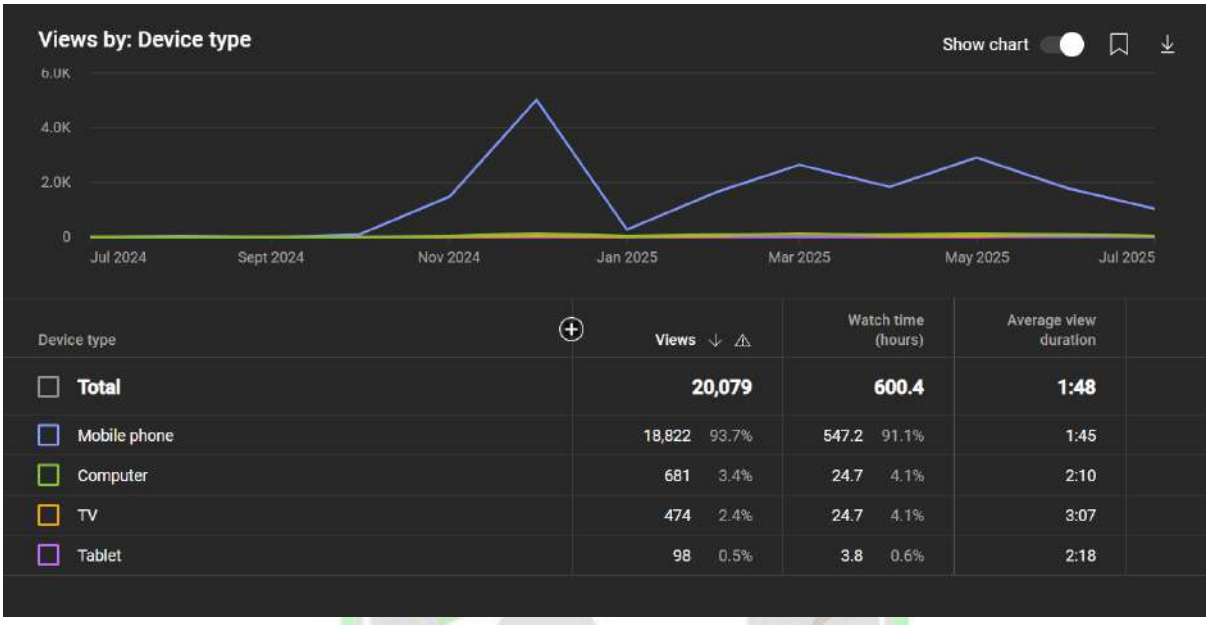

Image 4: Statistics of the views by device type in KVK Ooty Youtube Channel.

The Critical Role of Digital Extension in Modern Agriculture

Agricultural extension has always been the backbone of technology transfer from research institutions to farming communities. However, traditional extension methods face numerous challenges including limited reach, inconsistent messaging, and resource constraints. Digital platforms like YouTube offer solutions to these persistent problems by providing scalable, consistent, and accessible content delivery.

The KVK system, established as a district-level institution for technology assessment and demonstration, plays a pivotal role in bridging the gap between agricultural research and field application. When KVKs embrace digital platforms, they multiply their impact exponentially. A single well-produced video can reach hundreds of farmers simultaneously, providing consistent information that might otherwise require multiple field visits or training sessions.

Digital extension also offers the advantage of on-demand learning. Farmers can access critical information when they need it most, whether it's pest identification during an outbreak or

soil preparation techniques before planting season. This just-in-time delivery of knowledge can significantly impact decision-making and crop outcomes.

Social Media's Transformative Impact on Farmer Decision-Making

Social media platforms, particularly YouTube, have fundamentally altered how farmers access and process agricultural information. Unlike traditional extension methods that rely on scheduled meetings or visits, social media provides continuous access to a vast repository of knowledge. Farmers can compare different techniques, seek multiple opinions, and make informed decisions based on diverse perspectives.

The visual nature of YouTube makes it particularly suitable for agricultural extension. Complex farming techniques that might require hours of explanation can be demonstrated effectively in short videos. Farmers can observe proper application methods, timing, and expected outcomes, reducing the learning curve for new technologies.

Moreover, the interactive features of social media platforms enable two-way communication between extension workers and farmers. Comments sections become forums for discussion, where farmers can ask specific questions and receive targeted responses. This interactive element transforms passive information consumption into active learning experiences.

Horizontal Technology Spread Through YouTube

One of the most significant advantages of YouTube for agricultural extension is its potential for horizontal technology spread. When a farmer successfully implements a technique learned from a KVK video, they often become advocates for that technology within their community. The visual proof of success, combined with peer-to-peer recommendations, creates a powerful multiplication effect.

YouTube's algorithm-driven content recommendation system further amplifies this horizontal spread. As farmers engage with KVK content, the platform suggests related videos, potentially exposing them to additional technologies and practices they might not have otherwise discovered. This serendipitous discovery of new techniques can lead to innovative adaptations and improvements in farming practices.

The platform's sharing capabilities also facilitate technology spread. Farmers can easily share useful videos with family members, neighbors, and fellow farmers, creating informal networks of knowledge dissemination that extend far beyond the KVK's immediate reach.

Building Sustainable Digital Extension Communities

The success of KVK Ooty's YouTube channel demonstrates the potential for building sustainable digital extension communities. By consistently uploading quality content and engaging with their audience, they have created a trusted source of agricultural information that farmers actively seek out. This trust is crucial in agricultural extension, where the consequences of following incorrect advice can be severe.

The channel's focus on local relevance, with content specifically tailored to The Nilgiris' unique agricultural conditions, ensures high utility for the target audience. This localized approach, combined with the global reach of digital platforms, represents the ideal balance between specificity and scalability in agricultural extension.

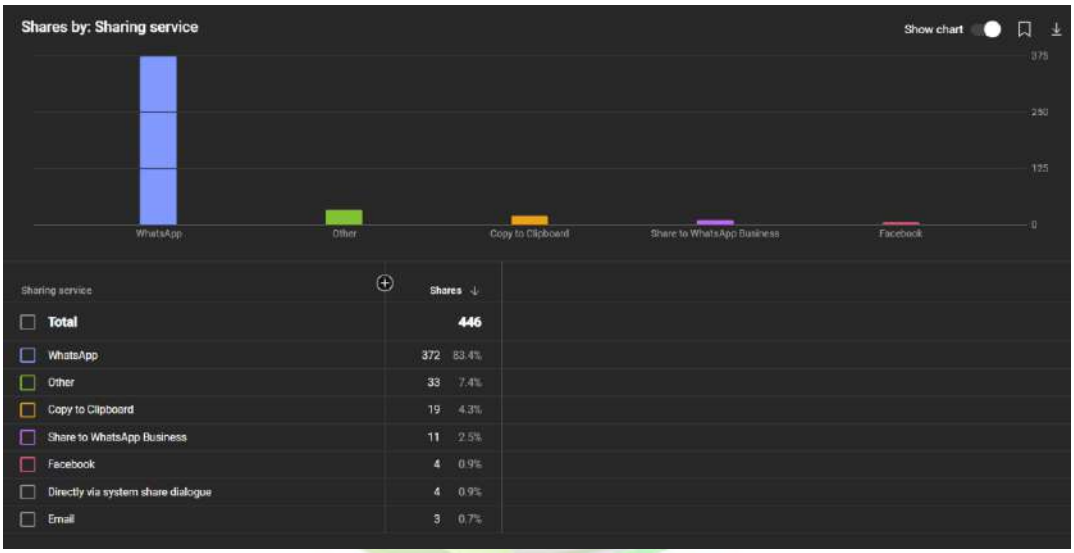

Image 5: Statistics of shares by sharing services in KVK Ooty Youtube Channel.

Future Prospects and Community Support

The KVK Ooty YouTube channel represents just the beginning of a digital extension revolution in The Nilgiris. As the channel continues to grow and evolve, plans are underway to upload more technology videos covering diverse aspects of agriculture relevant to the region. From climate-smart agriculture techniques to post-harvest management, the potential for content expansion is vast.

However, the success of this initiative depends not just on the KVK's efforts but on community support and engagement. Every subscription, view, and share contributes to the channel's growth and helps YouTube's algorithm recommend the content to more farmers.

Agricultural professionals, progressive farmers, and development organizations must actively support such initiatives by promoting the channel within their networks.

Conclusion: A Digital Bridge to Agricultural Prosperity

The KVK Ooty YouTube channel stands as a testament to the transformative power of digital extension in modern agriculture. By leveraging social media's reach and accessibility, the channel is making significant impacts on farmers' lives in The Nilgiris, providing them with timely, relevant, and practical agricultural knowledge that directly influences their decision-making processes.

As we look toward the future, the continued success of this digital extension model will depend on sustained commitment to quality content creation and active community engagement. The channel's growing influence on farmer decision-making and technology adoption in The Nilgiris serves as a model for KVKs across the country.

The time has come for the entire agricultural community to recognize and support such digital initiatives. By subscribing to the KVK Ooty YouTube channel, sharing its content, and encouraging others to engage with it, we collectively contribute to a common cause that has the potential to transform farmer livelihoods and enhance agricultural productivity. In this digital age, supporting a YouTube channel becomes an act of solidarity with farming communities and a investment in agricultural development.

The future of agricultural extension is digital, and KVK Ooty is leading the way in The Nilgiris, one video at a time.

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EMBEDDING CIRCULAR ECONOMY PRINCIPLES IN AGRIBUSINESS

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Abstract

The circular economy represents a transformative paradigm shift in addressing sustainability challenges within agribusiness by fostering closed-loop systems, resource efficiency and ecological regeneration. Departing from the traditional linear economic model of "take-make-consume-dispose" the Circular economy framework advocates prolonging the life cycle of resources through reuse, recycling, composting, renewable energy integration, and valorisation of agricultural residues. Applied to the agricultural sector, this approach strengthens soil health, reduces dependence on external inputs, and minimizes environmental degradation by optimizing resource flows and stimulating innovation across value chains. This paper critically examines the fundamental principles of Circular economy within agribusiness, highlighting tangible benefits, emerging practices and technological innovations. By analysing bio-based innovations, precision agriculture techniques and integrated farming models, this study underscores the potential of Circular economy to drive ecological, economic and social sustainability.

Introduction

The serious environmental crises, resource depletion and growing global food demand necessitate rethinking existing economic systems within agriculture. A circular economy provides a systemic solution, prioritizing resource longevity, waste minimization and the restoration of natural systems. The Circular economy model redefines traditional production and

consumption by promoting practices such as sharing, repairing, refurbishing and recycling to maintain materials in circulation for as long as possible.

This approach contrasts sharply with the dominant linear economic paradigm, characterized by a "take-make-consume-dispose" trajectory. The linear model's reliance on abundant, inexpensive raw materials and fossil fuels has led to unsustainable extraction rates, pollution and significant greenhouse gas emissions. The widespread phenomenon of planned obsolescence where products are intentionally designed with limited lifespans to encourage repeat consumption exacerbates waste generation.

In agriculture, the Circular Economy framework offers a regenerative alternative capable of reconciling productivity with environmental stewardship.

Reframing Economic Processes through Circularity

Transitioning to circularity requires a fundamental shift in how agricultural resources are managed. Circular economy involves designing systems where inputs, processes and outputs are interconnected in feedback loops, thereby extending resource utility and minimizing waste. Agricultural by-products such as crop residues and animal waste are not treated as disposable waste but as raw materials for bio-energy, fertilizers or animal feed. Water resources can be conserved through recycling and precision irrigation systems closing the loop in hydrological cycles.

This regenerative perspective aligns with natural ecosystems where biological processes inherently recycle nutrients and energy. Emulating ecological cycles in human-managed agribusiness systems is central to realizing circular economy promise.

Circular Economy in Agribusiness:

Agribusiness intersects with Circular Economy along two principal cycles:

1. The Technical Cycle

. Key interventions include:

- **Equipment Sharing and Refurbishment:** Instead of every farm owning costly machinery, cooperative models allow shared access, reducing capital costs and environmental footprints.
- **Sustainable Packaging:** Responding to consumer and regulatory pressures, food producers are adopting biodegradable and recyclable packaging materials to replace single-use plastics.

- **Renewable Energy Technologies:** Solar-powered irrigation systems and biogas digesters illustrate how farms can reduce dependency on fossil fuels while improving energy resilience.

2. The Biological Cycle

- **Composting and Anaerobic Digestion:** Organic waste streams are converted into bio-fertilizers and biogas, closing nutrient loops.
- **Integrated Crop-Livestock Systems (ICLS):** Crop residues feed livestock, whose manure fertilizes fields, enhancing nutrient cycling and reducing synthetic fertilizer use.
- **Agro ecological Practices:** Techniques such as crop rotation, poly cultures, and cover cropping improve biodiversity and soil health.

Core Principles Driving Circular Agribusiness

1. **Design out Waste and Pollution:** Proactive measures to eliminate harmful inputs, such as shifting from synthetic agrochemicals to organic alternatives and designing supply chains that minimize post-harvest losses.
2. **Maintain Product and Material Value:** Agricultural products and by-products are kept in use through innovative re purposing strategies (e.g., turning fruit peels into natural dyes or cosmetics).
3. **Promote Regenerative Natural Systems:** Restoration of degraded soils, improved water retention, and enhancement of ecosystem services ensures long-term productivity and resilience.

Why Should Agribusiness Embrace the Circular Economy?

The integration of Circular economy principles offers multifaceted benefits:

- **Environmental Sustainability:** Lower greenhouse gas emissions, reduced eutrophication, and improved biodiversity.
- **Economic Resilience:** Diversified revenue streams (e.g., bioproducts, renewable energy), reduced input costs and strengthened market competitiveness.
- **Social Benefits:** Creation of green jobs in rural areas and enhanced food security by stabilizing supply chains.
- **Alignment with Global Goals:** Supports Sustainable Development Goals (SDGs) such as zero hunger, responsible consumption and production, and climate action.

Applications of Circular Economy in Agribusiness

- **Precision Agriculture:** Technologies like drones, soil sensors, and AI-powered analytics enable site-specific management of water and nutrients, reducing waste and optimizing yields.
- **Waste-to-Value Innovations:** Examples include:

  1. **Biochar Production:** Sequesters carbon and enhances soil fertility.

  2. **Bioplastics from Agricultural Residues:** Offers eco-friendly alternatives for packaging and other uses.

Aquaponics Systems

Closed-loop systems combining aquaculture and hydroponics where fish waste provides nutrients for plants, and plants filter water for fish.

Agroforestry and Perennial Crops

Integration of trees into farming systems enhances carbon sequestration, diversifies farm outputs, and improves resilience to climate variability.

Challenges to Implementation

- **Economic Feasibility:** High initial investment costs deter smallholder participation.
- **Technological Limitations:** Gaps in access to advanced technologies in developing regions.
- **Policy and Regulatory Constraints:** Lack of enabling policies and incentives slows innovation diffusion.
- **Knowledge and Skills Gaps:** Farmers often lack awareness or technical expertise to adopt circular practices effectively.

Strategies for a Circular Transition

- Policy interventions offering subsidies or tax incentives
- Public-private partnerships to fund infrastructure (biogas plants)
- Capacity-building initiatives targeting farmers and agribusiness stakeholders.
- Development of market mechanisms to reward circular products (e.g., eco-labeling, carbon credits).

Conclusion

The adoption of circular economy principles in agribusiness is pivotal for transforming current food systems into sustainable, resilient and equitable models. By closing resource loops,

valorising waste streams and prioritizing regenerative practices. Circular economy enables a synergy between economic growth and ecological preservation. While challenges remainparticularly in financing, technological diffusion and policy alignmentstrategic interventions and cross-sectoral collaboration can accelerate the transition. Agribusinesses that embrace circularity will not only secure their long-term viability but also contribute significantly to global climate goals and rural development.

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PROBLEMS AND PROSPECTS OF AGRICULTURAL MARKETING IN INDIA

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Introduction

Agriculture is the heart of the Indian economy. Agriculture is contributing 14% to the national Gross Domestic Product, it supports the livelihood of more than half of the country's population. The sector's importance extends beyond food production and it drives demand in manufacturing and services due to increased rural consumption. Agricultural marketing encompasses activities such as procurement, quality grading, storage, transport, and sales of agricultural commodities.

Challenges in Agricultural Marketing

1. **Complex Regulatory Framework:** Numerous laws involving pricing, taxation and licensing complicate agricultural marketing in India. These regulatory hurdles often discourage private investment and innovation in the sector.
2. **Market Fragmentation:** India's agricultural marketing system is highly decentralized. A long chain of intermediaries adds to transaction costs, reducing the share of earnings for farmers.
3. **Outdated Marketing Channels:** Traditional systems, particularly *mandis*, continue to dominate. These are often plagued by inefficiencies, lack of transparency and corruption, limiting market access and farmer income.
4. **Lack of Marketing Skills:** Many farmers lack the expertise needed to effectively market their produce, negotiate fair deals or identify emerging market opportunities.

5. **Inefficient Supply Chains:** The agricultural supply chain often suffers from inefficiencies, especially for small and marginal farmers, leading to higher costs and limited market reach.
6. **Limited Market Information:** Farmers frequently operate without up-to-date data on supply-demand trends and pricing, leading to poor marketing decisions and financial losses.
7. **Insufficient Access to Finance:** Lack of affordable credit prevents farmers from investing in better inputs or marketing strategies.
8. **Underdeveloped Infrastructure:** Inadequate storage, poor transport facilities, and insufficient market spaces result in post-harvest losses and volatile prices.
9. **Limited Market Intelligence:** Farmers often do not have access to customer preferences, market trends, or demand forecasts, which make it difficult for them to plan production effectively.
10. **Inconsistent Quality Control:** Weak grading and certification systems reduce the competitiveness of Indian produce in both domestic and international markets.
11. **Low Product Quality:** Poor-quality seeds, traditional farming techniques, pest-related damage and weather variability contribute to substandard produce.
12. **Insufficient Market Price Information:** Due to poor communication infrastructure, farmers remain unaware of prevailing prices in major markets and end up accepting low prices.
13. **Multiple Intermediaries:** A long chain of brokers and middlemen reduces the share of profits reaching the farmer.
14. **Collection Challenges:** Aggregating produce from small-scale growers, an especially perishable item like vegetables is costly and logistically challenging.
15. **Lack of Market Awareness:** Many farmers are disconnected from market news and current developments, reducing their ability to sell at competitive rates.

Opportunities and Future Prospects

1. **Capacity Building:** Training programs can help farmers acquire marketing, negotiation, and entrepreneurship skills to access better markets.
2. **Development of Cold Chain Systems:** Investments in cold storage and refrigerated transport can reduce spoilage and improve the shelf life of perishable goods.

3. **Expansion of Contract Farming:** This model offers assured markets, better input access, and financial support while providing consumers with high-quality, traceable products.
4. **Direct-to-Consumer Models:** Initiatives like farmers' markets and community-supported agriculture reduce reliance on middlemen and enhance income for producers.
5. **Growth of E-commerce:** Digital platforms are increasingly connecting farmers directly with end-users, improving price realization and reducing marketing costs.
6. **Infrastructure Improvements:** Strengthening rural roads, storage facilities, and market yards can streamline the entire supply chain and cut post-harvest losses.
7. **Policy Reforms:** Amendments to the APMC Act and the adoption of the e-NAM platform have enhanced transparency and widened market access.
8. **Promotion of Organic Farming:** With rising demand for organic products, farmers have the opportunity to earn premium prices and ensure sustainable income.
9. **Public-Private Partnerships (PPPs):** Collaborations between the government and private sector can improve infrastructure, offer technical support, and expand credit access.
10. **Focus on Value Addition:** Processing raw agricultural products into finished goods enhances their marketability and profit margins.

Improving the Agricultural Marketing System

1. **Strengthen Market Research:** The government should allocate funds for research into market trends, consumer behavior and demand-supply dynamics.
2. **Expand Credit Facilities:** Farmers need accessible credit through rural banks and cooperatives to avoid dependence on informal moneylenders.
3. **Enhance Market Awareness:** Use mass media (TV, radio, print) to disseminate real-time information on prices, demand, and supply conditions.
4. **Invest in Transportation:** Build all-weather roads and enhance availability of vehicles to ensure timely delivery of produce to markets.
5. **Provide Training Programs:** Offer training in marketing management and regulated market systems to improve the skill sets of stakeholders.
6. **Encourage Product Grading:** Support and expand organizations that standardize and grade agricultural goods to ensure better market prices.

7. **Increase Awareness of Market Policies:** Ensure farmers are informed about government policies, MSPs and pricing through efficient communication channels.
8. **Develop Cold Storage Facilities:** Expand cold storage availability, specifically in rural and semi-urban areas, to reduce spoilage of perishables.
9. **Implement Product Standardization:** Establish quality labs in rural areas to promote consistent grading and standardization of farm goods.
10. **Improve Loan Accessibility:** Strengthen institutional credit support for small and marginal farmers through targeted financial inclusion programs.
11. **Organize Mandis:** Set up regulated mandis with fair systems for weighing, storage and payments to ensure transparency.
12. **Conduct Market Surveys:** Government agencies should gather and publish data on production, demand, pricing and export potential to guide marketing strategies.

Government Initiatives in Agricultural Marketing

The Government policies prioritized increasing production, the importance of efficient marketing has become to increase the system in efficiently. Without a strong distribution system, high yields not translate into better outcomes for farmers. Pre-independence days, the Indian government has taken multiple steps to modernize agricultural marketing. These include:

- Establishment of regulated markets
- Construction of storage and warehousing facilities
- Implementation of grading and standardization practices
- Broadcasting daily market prices via All India Radio
- Improving rural transportation systems

The Food Corporation of India (FCI) set up in 1965, plays a vital role in procurement and distribution under the public distribution system (PDS). Co-operative societies and state warehousing corporations have helped reduce post-harvest losses. More than 80% of grains in the PDS come from Punjab, Haryana and Western UP. The Agricultural Produce (Grading and Marking) Act, standards have been set for several commodities. The Department of Marketing and Inspection continues to conduct market surveys and support co-operative storage initiatives.

Conclusion

India stands among the top producers of agricultural goods globally. For farmers to realize fair returns, marketing systems must evolve alongside production practices. Reforming

and streamlining the agricultural marketing ecosystem with improved infrastructure, better policies, and stronger support systems will ensure sustainable growth and profitability for Indian farmers. An efficient and fair marketing strategy ensures that producers are compensated appropriately, strengthening both the rural economy and the broader national development framework.

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OKRA BREEDING

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Abstract

Okra is a significant vegetable crop that is grown in both the warmer temperate zones and the tropical and subtropical regions of the planet. Only the different developing nations in Asia and Africa engaged. According to reports, the widely grown okra is a tetraploid species with a vast and complicated genome that prevents it from improving genetically quickly using current omics technologies. Okra has frequently been genetically improved by the use of breeding techniques appropriate for self-pollinated crops, including plant introduction, pure line selection, hybridization followed by selection, mutation breeding, and heterosis breeding. Okra breeders have developed numerous varieties and hybrids in India through the use of pedigree selection and heterosis breeding. Investigating the genetic behavior of a few biological and economic characteristics of 14 okra populations gathered from the Dakahlia Governorate and subjected to two cycles of inbreeding with selection were the study's goals. In every generation, specific plants were chosen based on their minimum neck/pod ratio, large quantity of pods, and earlyness.

Keywords: biotechnology, breeding, genetics, okra, and genetic resources.

Introduction

Tropical and sub-tropical regions around the world are home to the commercially significant summer vegetable known as okra (Abelmoschus esculentus). One of the main crops

cultivated in India throughout the warm and rainy seasons is okra, commonly referred to as lady finger or Bhindi. It is distinguished by its characteristic beautiful blossom and is a member of the Malvaceae family of hibiscus. The majority of okra production—nearly 99 percent—occurs only in developing nations in Asia and Africa. To recover desirable families from okra, inbreeding combined with selection was more than enough. In this regard, Masoud et al. (2007), Moualla et al. (2005), and Hussein (1994) examined the economic and biological characteristics of a few families that emerged from using individual plant selection on a few okra populations. They discovered significant variation in every feature they looked at, and they concluded that enhancing these qualities should be lucrative and successful during the selection process.According to FAO estimates, Nigeria accounts for 12% of the okra market, while India accounts for 75%. Okra, the most prized and widely consumed vegetable in fresh, frozen, and dried forms, is cultivated as an irrigated and rain-fed crop. Red okra is becoming more and more popular in India since it is a fresh market sector and has potential health advantages because of its anthocyanin content (Karmakar et al., 2022). Globally, okra breeding is continually evolving with new problems, approaches, and techniques. The final objective of okra. The high prevalence of the virus, which is a member of the genus Begomoviral and family Geminiviridae, is discouraging small landholding farmers from cultivating the crop (Fauquet & Stanley, 2005). However, the goal of okra improvement initiatives worldwide has now switched to creating high-yielding F1 hybrids with desired market-driven features that are multiplely tolerant to biotic stressors.

Origin

Ancient Sanskrit literature mentions okra by the names tindisha and gandhumula. In the 12th century, it was well-known in Egypt. It's possible that African slaves brought okra to tropical and subtropical America in the early post-Columbian era. Okra's origin is still up for debate; it may have originated in Ethiopia, the upper Nile area of Sudan, West Africa, or Tropical Asia. While one possible ancestor (A. tuberculatus, 2n = 58) is native to Uttar Pradesh, India, indicating an Indian origin, another putative ancestor (A. ficulneus, 2n = 72) is found in East Africa, indicating a geographical origin in northern Egypt and Ethiopia (Charrier, 1984). Since A. caaillei is exclusively found in West Africa, it is challenging to propose an origin outside of that region.

Distribution of Abelmoschus sp

In the family Malvaceae, the genus Abelmoschus is well-known for its commercially important cultivated species, A. esculentus, or okra, which is farmed all over the world, but particularly in tropical and subtropical nations. Because of the great morphological diversity found there, the Indian subcontinent is regarded as the genus' center of diversification. Numerous Abelmoschus species may be found across India's phytogeographical zones, which range from the southern peninsula to the Himalayas.

Genetic Resources and Diversity

Natural or man-made crop plant evolution is mostly determined by the genetic variety already present in the population. The degree of variation between or within species is referred to as diversity. Differences between current inter- and intra-specific species provide the foundation of all crop development. There is more room for improvement in plant performance for several aspects when species variety or dissimilarity exists. Breeders can choose superior genotypes to be utilized as parents in a hybridization program or directly as new varieties thanks to the genetic variety found both within and across agricultural plant species. Two progenitors must be diverse in order to accomplish heterosis and create transgressive segregates. Therefore, the establishment of a resistant recombinant line or lines to YVMV and OELCV illnesses requires the identification of a suitable donor parent among cultivated okra species. Historically, genetic diversity has been assessed using a mix of morphological, molecular marker, and agronomic characteristics.

Cytogenetic Relationship in Okra

Cytological studies demonstrated that there are noteworthy differences for chromosome numbers and ploidy levels exist among the different species of Abelmoschus. The lowest chromosome number of 2n=56 was observed in A. angulosus (Ford, 1938), while the highest chromosome number close to 200 reported for A. manihot var. caillei or A caillei (Singh & Bhatnagar, 1975; Siemonsma, 1982a, 1982b). Cross ability relation and affinities between cultivated species A. esculentus and wild relatives established by various researchers on the basis of cytogenetic evidence. Joshi & Hardas (1956) and Joshi et al. (1974) observed that 29 of the 65 gametic chromosomes of A. esculentus had comprehensive homology with that of the A. tuberculatus (n=29). When compared to A. moschatus (n = 36), the other group of 36 chromosomes from A. esculentus showed higher similarity with A. ficulneus (n = 36). These

investigations identified A. esculentus as being amphidiploid (29 T+36 Y). Additional polyploidy species that exhibit genetic kinship include A. pungens, A. esculentus, and A. tetraphyllus.

Genetic Enhancement via Conventional Breeding

Okra is a frequently cross-pollinated crop because of its floral structure, which encourages self-pollination while also offering a 10-15% possibility of outcrossing. Okra is primarily bred using the autogamous breeding system, hence breeding techniques typically applied to self-pollinated crops can be applied to this crop to improve its genetic makeup. Plant introduction, pure line selection, backcross-based intraspecific and interspecific hybridization, heterosis breeding, mutation, and polyploidy breeding are the breeding procedures that are consistently used to enhance okra (Bisht & Bhat, 2006). Artificial mutagenesis using chemical or physical mutagens (such as gamma rays) can also produce variability (EMS). Through induced mutation from Pusa Sawani treated with 1% EMS, a mutant EMS-8 (Punjab-8) with resistance to YVMV and tolerance to fruit borer has been created (Singh et al., 2023). According to several research findings, using heterosis to increase okra yields by 50–70% was an impressive improvement (Jagan et al., 2013). A common method for increasing okra productivity is heterosis breeding. By introducing the resistant gene or genes, heterosis breeding in okra aims to boost production while also providing long-term protection against YVMV and OELCV infections. There have been reports of significant heterosis in yield and the features that contribute to it (Singh et al., 1977; Singh and Singh,1949).

Breeding for Viral Disease Resistance

Numerous biotic stressors, including viruses, nematodes, fungus, and insects, often harm the okra crop. However, the two viral diseases that pose the most danger to its agriculture in India are Okra Enation Leaf Curl Virus (OELCuV) and Yellow Vein Mosaic Virus (YVMV), both of which are spread by whiteflies. Although a production loss of 49 to 84% has been documented when the crop is infected 50 to 65 days after sowing, the amount of yield loss brought on by YVMV infestation in okra decreases with the delay in plant infection. However, depending on the age of the plant upon infection, OELCuV can sometimes be a more harmful disease than the previous one, resulting in yield losses ranging from 30% to 100% (Sanwal et al., 2014). It was discovered that this variety's resistance was conferred by two recessive alleles at

two loci (Singh et al., 1962). This kind of breeding approach produced okra types as Parbhani Kranti, Arka Anamika, Punjab Padmini, and Punjab-7 (Mishra et al. 2021).

Biotechnological Interventions

Although okra is a crop high in nutrients, little attention has been paid to using contemporary biotechnological technology for genetic modification. due to insufficient knowledge on genetics, molecular markers, and other molecular tools for okra breeding (Saini et al., 2020). Numerous issues that might impact okra's output and quality include pests, disease, and environmental stresses (Naveed et al., 2012). Chromosome engineering, RNA interference (RNAi), genome-wide selection (GWS), chromosome engineering, targeted gene replacement, next-generation sequencing (NGS), and nanobiotechnology are examples of high throughput biotechnological techniques that can be used quickly to improve okra (Mishra et al., 2017). Around the world, a number of contemporary biotechnology technologies have been used to enhance the genetics of okra.

Marker-assisted breeding

A biotechnological method called marker-assisted breeding makes it possible to more accurately and efficiently choose plants with desired characteristics. This approach entails locating and using molecular markers connected to certain genes linked to desired characteristics. Marker-assisted breeding has been used in okra improvement to hasten the creation of new cultivars with enhanced traits. To help create okra variants with improved resistance to diseases like Fusarium wilt, OELCV, and YVMV, for instance, researchers have employed molecular markers. Breeders can screen plants at the molecular level and choose individuals with the desired features early in development by finding markers associated with disease-resistance genes. This speed up the breeding process and lowers the time and cost needed to create new okra types resistant to disease.

Genetic engineering

Okra's nutritional profile has been improved via the use of genetic engineering. Okra has been successfully altered by researchers to include more vital elements, including vitamins and minerals. To address nutritional deficits that are common in some areas where okra is a main meal, for example, attempts have been undertaken to increase the amounts of vitamin A and iron. To lower the incidence of YVMV and OELCV in farmed lines of okra, unconventional breeding approaches and biotechnological techniques are used in tandem (Sanwal et al., 2014; Kumari et

al., 2017). According to Chowdhury and Kumar (2019), biotechnology advancements must be appropriately integrated and applied at the local level in okra.

Role of NGS and transcriptomics

The field of molecular breeding, which uses NGS technology, is primarily used to find and create SSR markers. This technique is a massively parallel sequencing (MPS) technology that has a very high throughput, is quick, inexpensive, and requires little template preparation (Singh & Singh, 2015). The technologies of direct RNA sequencing, RNA sequencing, and NGS may be useful. The creation of genomic SSR markers in okra using Roche 454 Titanium pyrosequencing technology was first documented by Ravishankar et al. (2018). 979,806 bp of data were converted into about 61,722 reads. They all came together to form 3735 contigs, of which 2708 included microsatellites.

CRISPR/Cas9 technology

The technologies of CRISPR-associated protein 9 (Cas9) and Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR) have transformed genetic engineering by offering an accurate and effective means of targeted gene editing. CRISPR/Cas9 technology has been used to induce precise genetic alterations with previously unheard-of precision in okra enhancement. To produce okra cultivars with better qualities, such greater resistance to certain diseases or higher drought tolerance, researchers have using CRISPR/Cas9. Because of its accuracy, CRISPR/Cas9 may modify specific genes without adding foreign DNA, allaying worries about genetically modified organisms (GMOs). This method provides new opportunities for customizing okra cultivars to satisfy the unique requirements of various environmental settings.

Future Prospective

Future okra research and development initiatives in India will primarily concentrate on increasing okra yield and maintaining India's leadership position in the world. Breeding okra varieties and hybrids with extremely high yield potential and long-lasting, consistent resistance to YVMV and OELCV infections is crucial to achieving the desired output. Future okra hybrids and varieties would be more adaptable, have numerous biotic and abiotic stress tolerances, be better nutrient-dense, and have higher storage quality, with an eye on both domestic and international export markets. To create types or hybrids that meet export requirements, special breeding efforts are necessary. The creation of an okra small core set that makes up a global

biodiversity panel must be included in future research projects for sustainable breeding efforts in okra;

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ERI SILK – THE POOR MAN'S SILK: EMERGING SECTOR FOR STRENGTHENING LIVELIHOOD IN TELANGANA AND BEYOND

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Introduction

Eri silk, also known as *Ahimsa silk*, is one of India's most unique and ethical silk varieties. Unlike mulberry or muga silk, eri silk does not require killing the silkworm to extract the thread. The moth emerges naturally from the cocoon, making this a cruelty-free and environmentally friendly form of silk production. Traditionally popular in Northeastern India, especially Assam and Meghalaya, this sustainable craft is now gaining attention in other parts of the country, including Gujarat, Bihar, Orissa etc..

Life Cycle of Eri Silkworm (*Samia ricini*)

The eri silkworm undergoes complete metamorphosis, progressing through four key stages—egg, larva, pupa, and adult. The female moth lays about 650 eggs per gram of Disease-Free Layings (DFLs).

Eri Silkworms

Pupal Shell

Adult

These eggs hatch into larvae that feed voraciously on castor leaves for approximately 20–25 days. Once matured, the larvae spin open-ended, spindle-shaped cocoons in two to three days. Unlike other silk varieties, the adult moth is allowed to emerge naturally, preserving the sanctity of life. The entire cycle from egg to moth completes in roughly 30–35 days, and farmers can rear five to six batches per year depending on climatic and host plant availability.

Geographical Distribution and Cultural Significance

Eri silk finds its cultural and commercial roots in the Northeastern states of India—primarily Assam, Meghalaya, Nagaland, and Arunachal Pradesh. The fabric is often woven into traditional shawls, garments, and ceremonial attire. Recently, Meghalaya's eri silk earned a prestigious Geographical Indication (GI) tag, affirming its regional uniqueness and cultural value. The recognition has not only brought pride to the region but also increased interest in this silk variety at a national level.

Economic Potential: Why Eri is Called the 'Poor Man's Silk'

Eri silk is widely referred to as the "poor man's silk" due to its affordability, minimal input requirements, and significant economic returns. **For example (Just to make understand):** One gram of DFL costs around ₹18 and contains approximately 650 eggs. With a survival rate of 65% (Approximately), about 423 larvae are expected to mature. Since it takes two cocoons to produce one gram of shell, the surviving larvae can yield around 211 grams of cocoon shell per gram of DFL. At a market rate of ₹900 per kilogram of cocoons, the income from one gram of DFL would be about ₹190. This means that from an investment of ₹1,800 for 100 grams of DFL, a farmer could earn approximately ₹17,000 in a single cycle, excluding costs related to labor and leaves. Such returns, especially from backyard rearing with basic care, offer a reliable and accessible side income for small and marginal farmers.

Silkworm Pupae as Nutritious Food

The benefits of Eri sericulture go beyond silk. After reeling, the silkworm pupae remain as a rich source of protein and omega-3 fatty acids. In Assam and several other Northeastern states, these pupae are consumed either boiled, sun-dried, or used in local chutneys. They serve not only as a low-cost nutritional supplement for rural households but also have economic value when sold in local markets. **Dr. Suraksha Chanotra**, Scientist-B at the CSB-P3 Unit in Kokrajhar, Assam, emphasizes that pupal utilization strengthens the value chain by enhancing both nutritional and income security for the rearing community.

Eri Silk worm prepupae
(3 days after harvesting)

Eri silk worm Pupae
(7 days after harvesting)

A case study from Telangana

Eri worms feeding on castor leaves

Gogulothu Geetha feeding castor leaves to Eri silk worms

Showing Eri silkworm cocoon in nets

Encouraged by this synergy, a tribal couple—**Guguloth John** and **Geetha**—initiated eri silkworm rearing in their home after guidance from their relative, **Mr. Dharavath Saicharan**. Saicharan, a Scientist-B at the Central Silk Board, currently posted in Assam, drew inspiration from the women-centric eri rearing systems in the Northeast. Motivated by their example, he helped John and Geetha rear their first batch using locally available castor. From just 10 grams of seed (Procured from CSB-ESSPC Hosur, Tamilnadu), they raised 500 mature worms and harvested 250 grams of cocoon shell. With this initial success, they now plan to rent agricultural land after the next castor season to scale up their operations and create a sustainable model of Eri cultivation in Telangana.

Eri's Emerging Potential in Telangana

Telangana, though not traditionally associated with eri silk, is naturally equipped to support its cultivation. According to the *Castor Outlook – March 2024* report from PJTSAU, the state has more than **1,580 hectares under castor cultivation**, especially in districts like **Mahabubnagar, Narayanpet, Nalgonda, and Jangaon**. **Castor (***Ricinus communis***) is the primary host plant for eri silkworms** and thrives in Telangana's dryland conditions, making it an ideal match for rearing. **In addition to this, both tapioca-based and castor-based eri culture offer farmers the dual benefit of silk production and income from byproducts—such as tapioca tubers and castor oil—which can be processed into a wide range of food, cosmetic, and industrial products,** thus creating multiple streams of revenue and adding value to existing cropping systems.

National Encouragement: Mann Ki Baat Recognition

The couple's efforts come at a time of renewed national interest in eri silk. In his 123rd *Mann Ki Baat* episode on June 29, 2025, Prime Minister Narendra Modi lauded Meghalaya's eri silk and celebrated its recent GI tag. He highlighted its cruelty-free and sustainable nature, its climate versatility (warm in winter and cool in summer), and its appeal to global markets seeking ethical textiles. The Prime Minister also praised the role of women-led Self Help Groups (SHGs) in promoting eri sericulture and encouraged all citizens to support such indigenous crafts under the *Atmanirbhar Bharat* and *Vocal for Local* initiatives.

Conclusion: Weaving a Sustainable Future

Eri silk isn't just a fabric—it's a thread of hope for rural India. With minimal investment, high profitability, ethical production, and post-reeling nutritional benefits, eri sericulture presents a multi-dimensional opportunity for sustainable rural development. Telangana, with its abundant castor resources and growing scientific engagement, is well-positioned to become a hub for eri silk outside the Northeast. With greater awareness, government support, and community participation, this forgotten silk can once again weave livelihoods, dignity, and economic resilience into the fabric of rural India.

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STARTUP AGRICULTURE

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Abstract

Agriculture transformed by the innovation of agri start-ups in the recent years. It's a perfect opportunity to boost their self-confidence. By 2050, yearly food grain output must rise to 333 million tonnes. The food grains production accounts for 15% of the land in India to cover only 8.7% of output. This implies that cutting-edge technology is necessary to advance Indian agriculture and satisfy the anticipated demand sustainably. Indian agricultural economy, agri startups have the potential to be human capital and undoubtedly the best partners for the expansion of agriculture driven by innovation. Agri start-up innovations can provide a valuable solution throughout the agricultural value chain. This indicates that a robust partnership with promising agricultural startups will be necessary for the long-term, innovation-driven expansion of Indian agriculture.

Introduction

India has the second-largest agricultural land area in the world and 60% of Indian rural households work in agriculture. The half of India's workforce is employed in agriculture highly reliant on farmers and agricultural laborers to provide with a means of subsistence. Modern approaches and strategies will undoubtedly improve agriculture and reduce the burden on farmers.

The transition from agriculture to agribusiness is one of the most common strategies used by aspiring farmers to enter the world of profitable agriculture. Agribusiness sector has

been inundated with bright, young people who are motivated by the ideas, passion and advancement needed to shift agriculture from a low-tech to a high-tech industry by implementing innovative technologies and business models.

The Development of Agribusiness

- The Green Revolution, which focused on high-yield crops and chemical inputs, marked the beginning of the agricultural modernization.
- Mechanization and precision farming were introduced to increase productivity
- Data-driven decision-making, automation, and sustainable practices are centred on tech-driven startups.

Obstacles Facing New Agricultural Businesses

- Significant Initial Investment: There are low options for venture capital and financial assistance.
- Farmer Adoption: Reluctant to embrace modern technology.
- Regulatory and Policy Obstacles: Complicated Government regulations impeding innovation

Government Programs for Agricultural Startups

By aiming to 'double farmers' income by 2022, the Government's motivation in driving agriculture policy is adequately reflected.

- The National Agriculture Market (eNAM) implementation, the introduction of a revamped Animal Produce and Livestock Marketing Promotion and Facilitation (APLM) Act, an increased focus on food processing infrastructure and the establishment and other supporting infrastructure is developed.
- Paramparagat Krishi Vikas Yojana (PMKVY), Pradhan Mantri Krishi Sinchai Yojana (PMKSY), promotion of Farmer Producer Organizations (FPOs), tax incentives and other forms of assistance have given a big boost to the industry's overall development
- Rashtriya Krishi Vikas Yojana (RKVY) program aims to turn agriculture into a profitable economic activity through a multifaceted strategy.
- Mission for Integrated Development of Horticulture (MIDH) aims to increase the high growth rate of horticultural crops

- National Food Security Mission (NFSM) aims to raise the output of cereals, pulses, oilseeds, nutrient-rich grains and commercial crops through productivity improvements.
- Safeguarding of agricultural production and the reduction of farmer risks through the Pradhan Mantri Fasal Bima Yojna (PMFBY).
- The government is distributing Soil Health Cards in an effort to promote the balanced usage of fertilizers and, ultimately, assist farmers in saving money by using them wisely.
- Adoption of neem-coated urea (NCU) is encouraged in order to regulate urea use, improve nitrogen supply to plants and reduce fertilizer application costs.

Conclusion

Agripreneurs are still attempting to address a number of new issues in the Indian agribusiness sector as agricultural start-ups in the country in their early stages. India has established a solid reputation for itself among the world's startup community. In addition, banks and financial institutions should rise to the task by providing farmers, businesses, incubators and accelerators with more innovative funding options.

The government has to assist in establishing incubators and grants with a focus on agritech. Creating a promising 'new-age distribution model' that allows for the smooth hybridization of related technology is essential for the success of agricultural startups. It is imperative that we create a single, integrated platform that allows farmers to access credit, purchase goods and gain information.

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PACKAGING INNOVATION

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Abstract

As consumer expectations is growing interest in innovative packaging solutions like active packaging beyond traditional methods. Active packaging is engineered to extend shelf life and enhance food safety while preserving quality. This is increasingly being accomplished by integrating natural functional compounds into eco-friendly materials. Tailored to specific food preservation needs, active packaging technologies can significantly curb spoilage and maintain product integrity. Components include oxygen absorbers, carbon dioxide regulators, ethylene removers, ethanol emitters, moisture controllers, antimicrobial elements, odor/flavor control agents and temperature-sensitive materials.

Introduction

Packaging serves multiple essential purposes in the food industry: it protects contents, maintains hygiene, enables convenient transport and communicates vital product information. Packaging fulfills these core requirements as per the growing demand for smarter packaging technologies. The primary function remains the protection of food from external factors such as microorganisms, chemicals, moisture, oxygen and light which can negatively impact shelf life. Active packaging introduces a more dynamic approach by responding to internal conditions within the package to help sustain food freshness and quality.

Active Packaging

Active packaging refers to packaging systems that go beyond passive containment and

actively engage with the packaged product's environment. It includes components that interact with the internal atmosphere to extend shelf life and maintain product safety and sensory attributes. Conventional packaging serves as a barrier but the active packaging systems help regulate or modify internal conditions.

Key Active Packaging Systems

- **Oxygen Absorbers**: Oxygen exposure accelerates spoilage by promoting oxidation and supporting the growth of aerobic microbes. Removing oxygen from packaging, especially in liquids and perishable items to helps delay nutrient loss, off-flavors and color changes, thereby improving shelf stability.
- **Carbon Dioxide Controllers**: Elevated CO_2 levels can inhibit microbial growth and are useful in packaging perishable proteins like meat and fish. Since CO_2 escapes more rapidly than oxygen through most plastics, a continuous supply often via sachets or embedded systems is needed to maintain desired levels within the package.
- **Ethylene Removers**: Ethylene is a natural plant hormone responsible for ripening. Fruits and vegetables continue to emit ethylene post-harvest which can speed up deterioration. Ethylene-scavenging technologies are used to extend the storage life of ethylene-sensitive produce like bananas, tomatoes and apples.
- **Ethanol Emitters**: Ethanol vapors act as antimicrobials and are effective in preserving intermediate-moisture foods and baked goods. They help delay staling and microbial decay, making them valuable in the packaging of items such as cakes, breads and cheeses.
- **Odor and Flavor Controllers**: Packaging can either prevent or absorb unwanted odors and off-flavors. Barrier packaging attempts to preserve product flavor while getting rid of unwanted odors inside the package since some materials can inadvertently absorb pleasant scents.
- **Moisture Regulators**: Excess moisture accelerates spoilage. Desiccants like silica gel, calcium oxide or activated minerals are commonly enclosed in sachets to absorb humidity and help prevent textural and microbial degradation, especially in dry food applications.
- **Antimicrobial Agents**: These materials are designed to slow down or inhibit the growth of spoilage organisms and pathogens. They extend shelf life by creating a hostile environment for microbes without the need for intensive sterilization processes.

- **Temperature-Regulated Packaging**: Advanced materials viz., insulating fabrics or self-heating containers, help maintain safe temperatures during distribution and storage. Examples include self-heating beverage cans and thermally insulated wraps, which are widely used for convenience meals.

Food Safety, Consumer Perception and Regulation

There are several critical concerns associated with active packaging that must be considered:

1. **Regulatory Approval**: All materials in contact with food must be approved for safety and compliance.
2. **Environmental Standards**: Active packaging must meet guidelines for environmental sustainability and waste management.
3. **Consumer Transparency**: Clear labeling is important to prevent misunderstanding or misuse of active packaging features.
4. **Microbial Impact**: Any chemical or microbial interaction must be evaluated for unintended effects, such as promoting harmful bacterial growth.

In some cases, active compounds may migrate into food. Such occurrences require strict regulatory scrutiny including toxicological testing and dose limitations to ensure consumer safety.

Conclusion

Active packaging offers exciting possibilities in modern food preservation, combining science and material innovation to meet growing consumer and industry demands. Its ability to prolong shelf life while maintaining quality and safety makes it a valuable tool in the food sector. These systems ranging from moisture control to antimicrobial functionality can be tailored to various food types. The broader implementation of active packaging will depend on factors such as cost, regulatory compliance and consumer acceptance.

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BIOCHAR: A SUSTAINABLE SOLUTION FOR SOIL HEALTH AND CLIMATE CHANGE MITIGATION

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Abstract

Biochar, a carbon-rich material produced via pyrolysis of organic biomass in low-oxygen conditions, has emerged as a promising sustainable solution for enhancing soil health and mitigating climate change. Its unique porous structure and chemical properties improve soil fertility by increasing water retention, nutrient availability, and microbial activity, thereby promoting crop productivity. Additionally, biochar acts as a long-term carbon sink, sequestering atmospheric carbon and reducing greenhouse gas emissions. Advances in biochar production techniques, transitioning from traditional methods such as brick kilns and iron retorts to modern technologies, have improved its efficiency and scalability. This review highlights biochar's role in sustainable agriculture and environmental management, emphasizing its potential to address soil degradation and contribute to global climate mitigation efforts.

Keywords: Biochar, Pyrolysis, Soil health, Carbon sequestration, Sustainable agriculture, Climate change mitigation, Biomass conversion, Soil fertility, Carbon sink, Environmental sustainability

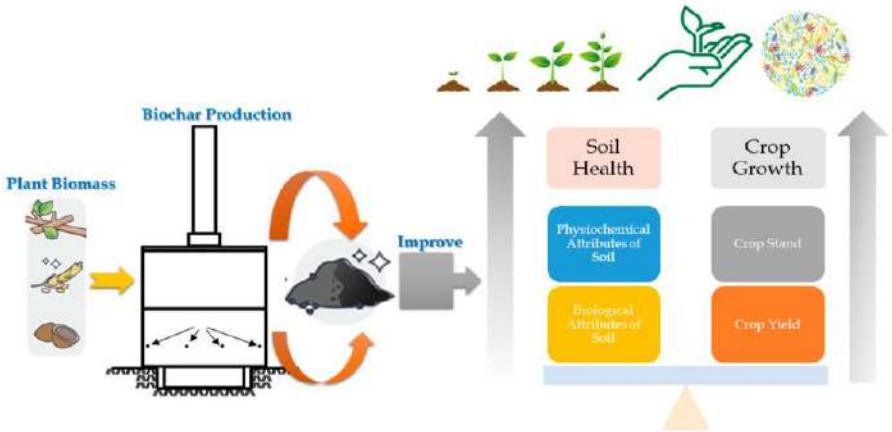
Introduction

In recent years, biochar has gained significant attention as an innovative and eco-friendly solution in both agriculture and environmental science. This charcoal-like substance is created by heating organic biomass such as crop residues, wood chips, or manure in a low-oxygen environment, a process known as pyrolysis. Rich in carbon, biochar presents a sustainable method for improving soil health, boosting crop yields, and storing atmospheric carbon in a

stable form. Its application not only enhances soil structure and nutrient retention but also contributes to long-term carbon sequestration, making it a valuable tool in the global effort to combat climate change. Biochar is a stable, carbon-rich material produced through the pyrolysis of organic waste such as crop residues and wood scraps in a low-oxygen environment. Unlike conventional charcoal, biochar is specifically designed for soil application and possesses distinct physical and chemical properties that make it highly effective in enhancing soil fertility. As rapid urbanization and population growth place increasing pressure on agricultural systems, leading to soil degradation and unsustainable farming practices fueled by excessive agrochemical use, biochar emerges as a sustainable solution. Its porous structure improves water retention, nutrient availability, and microbial activity, fostering healthier, more resilient soils. Additionally, biochar functions as a carbon sink, contributing to long-term carbon sequestration and helping to mitigate the effects of climate change. Understanding the processes that influence biochar's formation and its functional properties is essential to optimizing its role in promoting soil health, plant productivity, and environmental sustainability.

How Is Biochar Produced?

The production of biochar involves heating organic materials to temperatures between 300°C and 700°C in the absence of oxygen. This process decomposes the biomass into solid carbon (biochar), liquid (bio-oil), and gaseous (syngas) products. The resulting biochar is characterized by its porous structure, high surface area, and stability, which contribute to its effectiveness in various applications. The production of biochar techniques are mostly classified into traditional and modern methodologies, based on their developments and renovation.



Environmental Benefits of Biochar

By the non–stop growth and innovation of technologies, some of the traditional approaches for the production of biochar could frequently be replaced by means of modern techniques. The handmade–reactors like brick kilns, clay burners, firebrick pits, iron retorts were obviously utilized for the biochar production and the pits are enclosed by bricks (fire–brick pits and brick–kilns), clay, and metal burners (Iron–retorts). This kind of adapted technique for biochar preparation is convenient for the recovery as well as utilization of the so produced volatile compounds

1. Carbon Sequestration

One of the most notable environmental advantages of biochar lies in its exceptional capacity to sequester carbon. Through the pyrolysis process, a significant portion of the carbon contained in organic materials is transformed into a stable form that resists decomposition. When applied to soil, this stable carbon can persist for centuries even millennia effectively locking away carbon dioxide that would otherwise contribute to atmospheric greenhouse gas levels. This long-term storage reduces the amount of CO_2 in the atmosphere, making biochar a powerful tool in the fight against climate change. Research has shown that converting one ton of crop residues into biochar can sequester more than 920 kilograms of carbon dioxide, highlighting its potential for large-scale climate mitigation when integrated into sustainable agricultural practices.

2. Soil Fertility Enhancement

Biochar plays a vital role in enhancing soil fertility through several key mechanisms. Its highly porous structure improves the soil's ability to retain nutrients and moisture, while also enhancing aeration conditions essential for healthy root growth. By increasing the soil's cation exchange capacity, biochar helps retain essential nutrients, making them more available to plants and minimizing losses due to leaching. Moreover, biochar can raise the pH of acidic soils, creating a more favorable environment for crop growth. These combined effects make biochar an effective amendment for promoting long-term soil productivity and agricultural sustainability.

3. Reduction of Greenhouse Gas Emissions

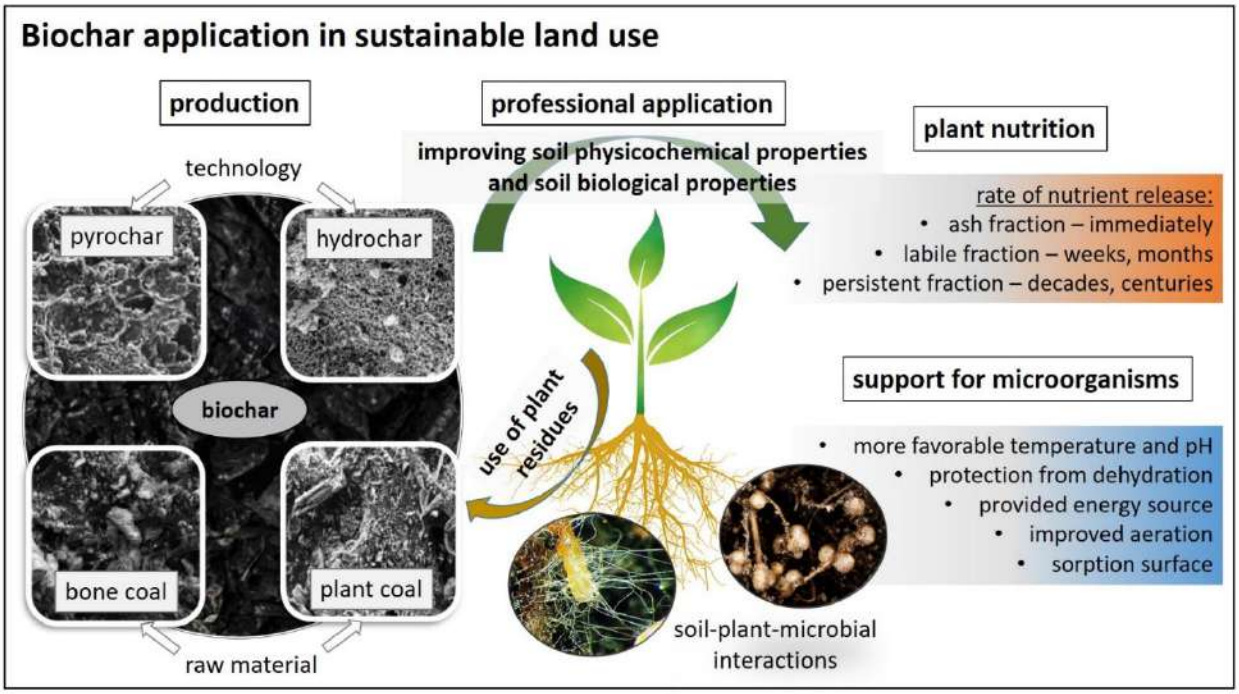
The application of biochar to soil offers a promising strategy for reducing emissions of powerful greenhouse gases such as methane (CH_4) and nitrous oxide (N_2O), both of which have significantly greater global warming potential than carbon dioxide. Biochar influences soil microbial activity, suppressing the processes like methanogenesis and nitrification that generate these gases. By altering soil chemistry and improving aeration, biochar creates conditions less

favorable for the microbes responsible for these emissions. As a result, incorporating biochar into agricultural practices not only enhances soil health but also serves as an effective tool for mitigating climate change.

4. Waste Management and Pollution Reduction

Biochar production provides an effective way to utilize various organic waste materials, such as agricultural leftovers, forestry by-products, and municipal organic waste. This process not only helps manage waste but also prevents the release of greenhouse gases that would result from the decomposition of organic matter. Additionally, biochar has the ability to adsorb heavy metals and other contaminants, effectively reducing soil pollution and improving environmental health.

Applications of Biochar



1. Agriculture

In agriculture, biochar is used to improve soil fertility, increase water retention, and foster plant growth. It is especially effective in revitalizing degraded soils, helping to restore soil health and boost crop production. Biochar's ability to retain nutrients and moisture reduces the need for chemical fertilizers and excessive irrigation, supporting more sustainable farming methods.

2. Carbon Credits and Climate Finance

Biochar's ability to sequester carbon has positioned it as a key asset in carbon offset

programs. For example, Google has partnered with the Indian supplier Varaha to purchase carbon credits generated from a project that converts agricultural waste into biochar. This collaboration underscores the increasing recognition of biochar's contribution to combating climate change.

3. Construction Industry

Biochar is also finding innovative uses in the construction industry. Researchers at RMIT University in Melbourne have developed a technique to transform used coffee grounds into biochar, which can replace up to 15% of sand in concrete. This biochar-infused concrete not only improves its strength but also reduces the amount of cement required, leading to a decrease in greenhouse gas emissions from concrete production.

Challenges and Consideration

Despite its many advantages, the widespread use of biochar faces several challenges. The properties of biochar can vary significantly depending on the feedstock used and the production methods, leading to inconsistent outcomes. Moreover, the high production costs and the need for comprehensive, long-term studies on its impact hinder large-scale adoption. Overcoming these obstacles will require additional research, standardization of production techniques, and strong policy support to encourage the use of biochar across different industries.

Conclusion

Biochar offers a versatile and effective approach to addressing critical environmental issues such as soil degradation, waste disposal, and climate change. Its capacity to store carbon long-term, improve soil health, and lower greenhouse gas emissions positions it as a powerful tool for advancing sustainable agriculture and environmental protection. As research and innovation in this field continue, biochar holds great promise in contributing to a more sustainable, resilient, and climate-friendly future.

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IMPORTANCE OF RICE BEAN CULTIVATION

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Introduction

Rice bean (*Vigna umbellata*) is one of the summer legumes grown by subsistence farmers in hill areas. It is known by different local names in different parts of the country, such as Masyang, Jhilinge, Gurous or Siltung. It is a neglected crop grown under diverse conditions with no additional inputs. It thrives well in marginal lands, rain-fed *tars*, drought-prone areas, and exhausted soils. It is generally grown as a mixed crop or intercrop with maize. It is also cultivated along rice bunds and terrace-margins in the mid hills. Rice bean is one of the minor legumes grown by Nepalese farmers and its area under cultivation is too low compared to other legumes as lentil, black gram and chickpea. There is an increasing trend in area, production, and productivity of grain legumes in the country (Neupane, 2003). However, in recent years farmers are gradually decreasing rice bean cultivation and the productivity has also gone down. The shading effect of the high yielding maize varieties and increasing use of chemical fertilizers in maize field has led to excessive vegetative growth, poor pod formation and low productivity of rice bean. Moreover, its consumption is declining due to increased availability of other preferred pulses in local markets (Joshi *et al.*, 2006). It is mainly used for human dietary uptake, with a smaller proportion used for fodder and green manuring (Joshi *et al.*, 2006). It forms an important part of cereal-based diet as the dried grains are rich in protein, minerals, and vitamins. Besides, it carries social and cultural values in some communities in the country. Promotion of this crop could play an important role in improving diet and food security of people.

Origin and Distribution

Rice bean is a native of South and South East Asia. Rice bean occurs in India, Myanmar, Malaysia, China, Korea, Indonesia, and the Philippines (Chandel et al. 1988; Gupta et al. 2014). West Indies, USA, Australia, East Africa, Java, Fiji, Bangladesh, Sri Lanka, and Nepal are cultivating rice bean in limited scale. It is well adapted to sub-tropical dry to moist climate. It grows well at 24-28°C with 1500-2000 mm rainfall. In India, the distribution is mainly found in the tribal regions of North-eastern hills and hilly tracts of Western and Eastern Ghats. The ethnic people of North-eastern states have predominantly grown rice beans as a mixed crop in jhum fields. The Eastern peninsular tract (Orissa and Chhotnagpur) and the Western peninsular tract of Southern hills have grown rice bean on a limited scale.

Rice bean is a legume crop cultivated in Nepal and North-eastern hilly areas of India. In kharif season, this crop is being cultivated as an intercrop along with maize. Among the pulse crops, the rice bean offers tremendous potential for expansion in North-eastern India. As a short-duration and close-growing crop with tender stems and green foliage even at maturity, the centre of origin and diversity of ricebean is Indo-China (Tamookaet *al.*, 1991). It is believed that ricebean evolved from its wild form, *Vigna umbellate* var. *gracilis*, whichis typically small leaved, fine-stemmed, freely branching, photoperiod sensitive with indeterminate growth habit, sporadic and asynchronous flowering, and strongly dehiscent pods with small and hard seeds. Ricebean is known for its diverse distribution and range of adaptation from humid subtropical to warm and cool temperate climate. Ricebean is distributed from southern China through the north of Vietnam, Laos, and Thailand to Burma, India, and Nepal. Its successful cultivation in Queensland and East Africa has also been reported. Furthermore, there are reports that ricebean cultivations common in Honduras, Brazil, and Mexico too. In Nepal, it is cultivated in marginal lands of mid hills and few farmers from inner terai grow ricebean in their home gardens. Potential districts of Nepal growing ricebean are categorised based on the area of coverage. Th e comparison of ricebean growing districts indicates that the area under this crop is higher in the Western Development Region of Nepal

3. Varietal Diversity of Ricebean

Ricebean is an annual legume with an erect to semi-erect vine that may grow to more than three metres height. It produces profuse branching. Leaves are tri-foliate, leaflets being comparatively broader and hairy. Flowers are conspicuously bright yellow and borne in clusters.

Some researches in India have shown that ricebean has the highest growth efficiency and lowest respiratory loss of seed reserves. Ricebean is a diploid (2n=22) and there is some evidence of natural out-crossing (Sastrapradja and Sutarno,1977). It has elongated, slightly curved and beakedseeds of variable size and colour with predominanthilum.In Nepal, there are very few scientific studies conducted on ricebean, and little has been done toassess its diversity and to promote it as a livelihoodsupporting grain legume.

Th e preliminary studies have indicated that there exists a high diversity of ricebean landraces in Nepal. The locally collected ricebean accessions exhibited a range of molecular diversity in astudy screening the SSR markers for polymeric loci. It has giveninsight to genetic structure and relationships of these accessions which could be used in breeding of improved varieties of ricebean (Bajracharya *et al.*, 2008). The study on preferred trait analysis showed that farmers gave diff erent names to ricebean landracesbased on grain colour and size. A study in Gulmi district indicated that farmers cultivate mainly four types of ricebean landraces: red (*RatoJhilinge*), brown big (*Khairo Th ulo*), white big (*Seto Th ulo*), andearly maturing small-grained semi-determinate (*Bhadaure*). Thedistinct characteristics of these landraces with their positive and negative traits as identified by farmers are presented. The twining habit of ricebean landraces makes them highly suitable togrow as intercrop with maize. However, it also makes them difficult to harvest mechanically, and in extreme cases additional staking isrequired to support the weight of vegetative growth. The landracesare susceptible to shattering. Hard-seeded ness is common in ricebean, although this trait does not appear to be consistent within varieties. Rice Bean (Vigna Umbellata) is a promising multipurpose legume crop with good potential as food, fodder, green manure and a cover crop.

The driedseeds are usually cooked and eaten with or without rice, young immature pods and leaves are used as avegetable. The seeds contain a higher amount ofprotein (20.9%) and limiting amino acids, tryptophan (0.79–1.10%) and methionine (0.45–1.18%), which rank it as one of the best among pulses (NAS, 1979).Though it is suited for the low land humid tropics, someof the cultivars are also adapted to subtropical conditions in the plains. It does well in sandy loam to heavy soils. It is also reported to be moderately drought tolerant (Duke, 1981). In India, its distribution is mainly confined to the tribal regions of the hilly areas of northeasternhills and the Western and Eastern Ghats (Arora et al., 1980; Chandel et al., 1984). Field evaluation of 530 accessions of rice bean for 36 descriptors at NBPGR, New Delhi, revealed a wide range

ofvariation for several traits and considerablevariation existed between collections from differentgeographical areas (Chandel et al., 1988). Analysisof the biochemical constituents of rice bean seeds (15–16) revealed variation for crude protein (17.8–25.2%), ash (3.8–4.1%), calcium (315–450 mg 100g_1), phosphorus (197–393 mg 100 g_1), iron (1–5 mg100 g_1). RBL-1 has been released for cultivation.

Nutritive Value

Ricebean is highly nutritious. The dry seeds of ricebean are good sources of carbohydrates, proteins, minerals, and vitamins. Proteinin ricebean is rich in limiting amino acids methionine and tryptophan (Carvalho and Vieira, 1996). Th e seeds are also rich in other aminoacids including valine, tyrosine and lysine (Mohan and Janardhan,1994). The seeds contain vitamins such as thiamine, riboflavin, niacinand ascorbic acid (Joshi et al., 2006). A laboratory study by Buergelt (2009) has also proven ricebean to be a good source of various nutrients

Biochemical constituents of ricebean

Sl.No.	Constituent	Range (%)
1.	Carbohydrate	58.2 - 72.0
2.	Crude protein	18.3 - 32.2
3.	Ash	3.5 - 4.9
4.	Soluble ether extract	0.1 - 0.5
5.	Crude fibre	3.6 - 5.5

Source: Buergelt et al., 2009

Rice bean is a multipurpose crop as it can be used as food, fodder, green manure, and cover crop. The dried seeds are usually eaten boiled or as a pulse, while young, immature pods are used as vegetables. Immature pods and bean sprouts are highly recommended in nutritional diet of Philippines. The entire plant could be used as forage for livestock. Animal readily eats the foliage, green pods, immature seeds, and flowers.

The seeds are good for broiler ration. In China, Japan and Korea, beans are generally ground into flour and meal; beans are often boiled and eaten as soup. Farmers of North-eastern and eastern India commonly eat green pods raw and cooked as a vegetable. Unripe seeds are boiled and sold as snacks in the village markets. Dried beans are cooked and combined with rice in many dishes. After the harvest, plants and pods are fed to cattle. The nutritional quality of rice bean has been reported to be the best among all the traditional pulses because of their high

protein and appreciable quantities of two limiting amino acids: methionine and tryptophan. It contains high-quality vitamins: thiamine, niacin, and riboflavin. Calcium and iron contents are also appreciably high. After 40 to 60 days old crops, the young leaves and immature pods are steamed for eating as vegetables. Rice bean is also an acceptable substitute for soybean sprouts. It contains 20-22% protein and a high Ca and carbohydrates (60%).

Common Uses of Ricebean

Ricebean is a crop with multiple use values. Several food items areprepared locally from ricebean. Th e seeds, which are the primary products, are usually taken as a soup or as a pulse (*Dal*) with rice.The grains from young pods are used as vegetable. *Batuk, Bara,Biraunla, Masyaura, Kwanti, Rot, Furaula,* and *Khichadi* are othermajor local recipes prepared from ricebean. Ricebean has cultural and religious values in Nepalese society. *Batuk* and *Bara* are used during marital ceremony and other socialfunctions in Magar and Newar communities respectively.

TheNewar community has a tradition of preparing soup *(Kwanti)* froma mixture of nine grain legumes during the festival of *Janai-Purnima* and ricebean constitutes one of these grain legumes. *Khichadi* is atraditional dish prepared from a mixture of rice and black gram orrice bean on the occasion of *Maghe-Sankranti*, a festival celebrated by Nepalese during mid-January. During *Gaura Parba*, a festival celebrated widely in far-western region of Nepal, ricebean is one ofthe five grains used in preparing *Biruda*, an off ering that is made tothe festival deity.Ricebean foliage is highly nutritious animal fodder. Some farmersinclude this crop in their cropping system to increase soil fertility.Ricebean is also used as a cover crop in hills as it is deterrent againstsoil erosion.Farmers prefer ricebean varieties that have high potential grain yield.Also, they equally consider fodder yield while selecting a ricebeanvariety because livestock is an integral part of the Nepalese farmingsystem

Utilisation

Rice bean is a multipurpose legume, sometimes considered as neglected and underutilised (Joshi et al., 2008). However, thoughless important than cowpea (Vigna unguiculata), adzuki bean (Vigna angularis) and mung bean (Vigna radiata), rice bean is a locally importantcontributor to human nutrition in parts of Indiaand South-East Asia (Joshi et al., 2008; Tomookaet al., 2011). All parts of the rice bean plant areedible and used in culinary preparations. The dryseeds can be boiled and eaten with rice or they canreplace rice in stews or soups. In

Madagascar, theseare grounded to make nutritive flour included inthe food for children. Unlike other pulses, ricebeans are not easily processed into dhal, due totheir fibrous mucilage that prevents hulling and separation of the cotyledons (Rajerison,2006; Ecoport, 2014; van Oers, 1989). Young pods, leaves and sprouted seeds are boiled and eaten asvegetables. Young pods are sometimes eaten raw (Rajerison, 2006). Rice bean is useful for livestock feeding. The vegetative parts can be fed fresh or made into hay and the seeds are used as fodder. Rice bean straw indudes the stems, leafy portions, empty pods, and some seeds . Before feeding, the woody portions and soiled or mildewed parts of the straw should be removed (Göhl, 1982). In the marginal hills, farmers consider rice bean both as a grain and fodder legume and look for dual-purpose landraces (Khanal et al., 2009). Rice bean is also grown for green manure, as a cover crop, and used as a living fence or biological barrier (Ecoport, 2014).

SCIENTIFIC CULTIVATION AND MANAGEMENT PRACTICES

Ricebean is ideal for catch-cropping, intercropping, and multiple-cropping systems. Also, it serves as an excellent cover crop and green manure crop-Rice bean is reported to produce 3000 kg of grain and up to 8000 kg/ha of dry herbage, serving as an essential source of green forage during lean period ie. April-June and November-December in northern India. Rice bean is a good source of protein with up to 24% seed protein concentration, has a very high in vitro digestibility of up to 82-85%. This crop is essentially grown as rainfed. In Nagaland, it is cultivated over 4,630 ha, producing 5,060 tonnes with productivity of 1.092.9 kg/ha. In North-eastern India, rice bean is an essential component of the 1.7 million ha area of shifting cultivation for the upliftment of the socio-economic condition of the farmers. Most of the local landraces of rice bean, available with farmers, are highly photosensitive in nature.

Botanical Description

Rice bean is a highly branched annual with erect or semi-erect stem tending to be viny. The bright yellow flowers occur in clusters along with axillary raceme inflorescence. Pods are slender, somewhat curved. Seeds are oblong with varying seed coat as smooth, dark wine, green, yellow,

Distribution

Rice bean originated from Indochina and was probably domesticated in Thailand and neighbouring regions (Tomooka et al., 2011). It is found naturally in India, central China and in the Indochinese Peninsula. It was introduced to Egypt, to the East Coast of Africa and to the

islands of the Indian Ocean. It is now cultivated in tropical Asia, Fiji, Australia, tropical Africa, the Indian Ocean Islands as well as in the Americas (USA, Honduras, Brazil and Mexico) (Rajerison, 2006; van Oers, 1989; Khadka et al., 2009). In the middle hills of Nepal, rice bean is cultivated along rice bunds and terracemargins (Khadka et al., 2009). Though it can thrive in the same conditions as cowpea and can better tolerate harsh conditions (including drought, waterlogging and acid soils), rice bean remains an underutilised legume and there is no breeding programme to improve this crop. Farmers must rely on landraces rather than on cultivars (Joshi et al., 2008). Rice bean is a fast summer-growing legume found from sea level up to altitudes of 1500 m in Assam and 2000 m in the hills of the Himalayas (Khadka et al., 2009). Rice bean requires a short day length to produce seeds.

It is grown on a wide range of soils including shallow, infertile or degraded soils. High soil fertility may hinder pod formation and reduce seed yield (Khadka et al., 2009). Vigna umbellata is a versatile legume that can grow in humid subtropical to warm and cool temperate climates. It is suited to areas with annual rainfall ranging from 1000 to 1500 mm but it is also fairly tolerant of drought. It does better in areas where average temperatures range from 18 to 30°C, tolerates 10-40°C but does not withstand frost (Rajerison, 2006; Ecoport, 2014). It prefers full light and its growth can be hampered if it is intercropped with a tall companion crop that overshadows it, such as maize (Khadka et al., 2009).

Forage management

Establishment and harvest

In India, rice bean is sown in February and March for harvest during summer and in July and August for harvest in December (Khanal et al., 2009; Oommen et al., 2002). It can be sown alone in small fields or along bunds of rice terraces. Rice bean benefits from being sown between rowsof a tall cereal such as maize or sorghum that it can use for climbing. Rice bean is a hardy plant that is resistant to many pests and diseases, and it does not require fertilizer or special care during growth. Farmers clip the tips of the plant to promote pod formation. Rice bean usually matures in 120-150 days after sowing but may need more time at higher altitudes. Seeds are harvested when 75% of the pods turn brown. Harvesting is best done in the morning or late afternoon to reduce the risk of heatinduced shattering. After the harvest, the vines and pods remain on the ground for 2-3 days after which the plants are threshed. The crop residues can then be used as fodder (Khanal et al., 2009). In India, late maturing and photosensitive landraces of

rice bean are cultivated as a fodder crop. They are sown during long-day periods in order to prevent the plant from flowering (Oommen et al., 2002). Dual-purpose varieties may be cut when the pods are half-grown, but the hay should be handled as little as possible because the leaves drop easily (Göhl, 1982).

Yields potential of rice bean

The seed yi eld of rice bean is about 225 kg ha-1 worldwide (Duke, 1981). It can however, vary from 200-300 kg ha-1 in West Bengal to 1300- 2750 kg ha-1 in Zambia, Brazil and India (Chandel et al., 1988; Chatterjee et al.,1977). In Bengal (India), fodder yields were reported to range from 5-7 t DM ha-1 in May and June, to 8-9 t DM ha-1 in November and December (Chatterjee et al., 1977). Lower values have been reported, 5-6 t DM ha-1 in Myanmar (Tin Maung Aye, 2001), and 2.9 t DM ha-1 in the sub-humid Pothwar plateau of Pakistan (Qamar et al., 2014). In India, rice bean grown with Nigeria grass (Pennisetum pedicellatum) yielded 7.6 t DM ha-1 after the application of 20 kg N ha-1 (Chatterjee et al., 1977). In Pakistan, rice bean grown with sorghum (50:50 mix) yielded up to 12 t DM ha-1 (Ayub et al., 2004). Rice bean is an N-fixing legume that improves the N status of the soil, thus providing N to the following crop. Its taproot has a beneficial effect on soil structure and, when ploughed in, returns organic matter and N to the soil. Rice bean grown before or after a rice or maize crop is beneficial. In Thailand, it is profitably sown between the rows of maize once the crop has reached maturity but before harvest so that rice bean covers enough soil at harvest. It is then possible to harvest the rice bean, thresh to obtain the seeds and bring the dry plants back to the field where they provide soil cover for the dry season (Echo AIC, 2012). In the Thai highlands, rice bean is a valuable green manure which outcompetes other legumes such as Canavalia ensiformis, Lablab purpureus and Mimosa diplotricha in their ability to improve rice yields (Chaiwong et al., 2012). In China, rice bean used as green manure in tangerine orchards resulted in higher fruit yields than soybean (Glycine max), mung bean (Vigna radiata) and cowpea (Vigna unguiculata) (Wen MingXia et al., 2011).

Rice bean forage

Data on the composition of rice bean forage is scarce. Like other legume forages, fresh rice bean forage is relatively rich in protein, though its concentration is extremely variable (17-23% DM). Rice bean hay and straw are slightly less nutritious (16 and 14% protein in the DM, respectively). Rice bean forage is also rich in minerals (10% of the DM in the fresh forage) and

particularly in calcium (up to 2% in the fresh forage). Rice bean straw contains large amounts of mineral matter (more than 20% of DM) though it is highly variable. Rice bean forage contains variable amounts of condensed tannins (0.1-2.8% DM) (Wanapat et al., 2012; Chanthakhoun et al., 2010).

Rice bean seeds

Rice bean seeds are rich in protein (18- 26% DM), though generally less than pea (Pisum sativum) or cowpea (Vigna unguiculata). They contain limited amounts of fibre and fat (about 4 and 2%, respectively). The amino acid profile is comparable to that of other grain legumes. It is relatively rich in lysine (more than 6% of the protein) but poor in sulphur-containing amino acids. Rice beans have a high starch concentration with reported values ranging from 52 to 57% of the DM (Kaur et al., 1990; Chavan et al., 2009). The amylose content of the starch is extremely variable from 20 to 60% (Kaur et al., 2013).

Rice bean as a potential resource as a fodder crop

Palatability

Rice bean forage at the pre-flowering stage is palatable to sheep (Chandel et al., 1988). In Nepal, farmers have emphasized the softness and palatability of rice bean fodder for livestock (Joshi et al., 2008). In an experiment with rice bean hay in India, bullocks consumed it hesitantly at first but within a few days the animals grew accustomed to it and DM consumption increased, indicating that the hay was palatable (Gupta et al., 1981). Rice bean straw was reported to be relished by cattle (Göhl, 1982).

Fresh rice bean forage

In India, 22 month-old calves fed a mixture of fresh Sudan grass (Sorghum × drummondii) and rice bean forage (54:46 fresh basis) for 64 days had a DM intake of 1.90 kg DM/100 kg LW and a daily weight gain of 456 g day-1 (Singh et al., 2000). In India, 22 month old calves fed a mixture of fresh Sudan grass (Sorghum × drummondii) and rice bean forage (54:46 fresh basis) for 64 days had a DM intake of 1.90 kg DM/100 kg LW and a daily weight gain of 456 g/d (Singh et al., 2000).

Rice bean hay

Rice bean hay is generally used as a protein source to supplement poor quality roughage-based diets in ruminants. Rice bean hay included at 600 g day-1 to supplement rice straw in diets for swamp buffalo increased DM intake, digestible protein and N retention. It had a positive

effect on rumen microflora, resulting in increased VFA production and lower CH4 emissions (Chanthakhoun et al., 2011). Adding rice bean hay was reported to increase cellulolytic rumen bacteria thus improving the utilization of high fibrous feeds in buffalo diets (Chanthakhoun et al., 2010). In India, a trial with bulls showed that rice bean hay had a moderate OM digestibility (50%) but that it contained nitrogen, calcium and phosphorus in adequate amounts to meet the maintenance needs of adult cattle (Gupta et al., 1981). In Vietnam, a mixture of cassava hay and rice bean hay (3:1 ratio) replaced 60% of concentrate in a forage-based diet (Pennisetum purpureum + urea-treated rice straw) offered to growing crossbred heifers, resulting in higher daily weight gain (609 g day-1), better feed efficiency and reduced feed costs (Thang et al., 2008). In India, supplementing local goats fed grass with rice bean hay (15% of diet DM) did not increase grass intake but total DM intake and nutrient digestibility were increased. Increasing the level of rice bean level above 15% had no further effect on digestibility (Das, 2002).

Rice bean straw as a fodder

In India, a trial with bullocks showed that rice bean straw had a low OM digestibility (31-47%) and it was recommended to supplement a rice straw-based diet with energy-rich feed materials, such as cereal grains or bran (Chaudhuri et al., 1981).

Rice bean seeds as a feed

In India, rice bean seeds are fed to buffalo calves and sheep to provide energy. Rice beans replaced half the cereals and half the deoiled cake present in the concentrate offered to buffalo calves (Ahuja et al., 2001). In sheep, replacing 50% of the metabolizable energy from oat hay by rice bean seeds had no deleterious effect on sheep N balance, which remained positive (Krishna et al., 1989).

Conclusion

From above review it can be concluded that rice bean is a vibrant potential fodder legume crop which has capacity to provide balance diet to the livestock and to sustain under wide range of climatic condition. Appropriate focus on the crop is needed for more popularity as a potential legume crop under the climate change situation.

Climatic Conditions for Ricebean

Study shows that ricebean can be grown in diverse environments due to its wide adaptation. Normally, it is sown in late-May to end-June in Nepal. Th e middle hills (700-1,400m asl) with warm south facing aspects are suitable for ricebean, although there is evidence

that it can thrive in altitudes as high as 2,000m asl (Lohani, 1980). A temperature range of 25-35º C and average rainfall of 1,000-1,500mm per annum is optimal for healthy vegetative growth and proper pod development. Farmers believe that heavy rain during flowering period affects the pod development and hampers ricebean production (Poudel, 2008). Most varieties are photoperiod-sensitive, tend to be late in flowering, and produce vigorous vegetative growth when grown underconditions of ample water and warm temperature in the subtropics. Studies in Assam of India (S. B. Neog pers. com.) and Jhapa district of Nepal (own data) have shown some possibility of promoting this crop in winter fallows, although it needs verifi cation. If this is verifi ed, then winter fallows in the Terai region of Nepal could be better utilised by farmers (LI-BIRD, 2008). Ricebean as a post rainy season crop in *Ghaiya*(upland rice) based and maize based system has also shown promise in low hills of Nepal.

Cultivation Practices

Land Selection

Ricebean is best adapted to drought-prone sloping areas and flat rain-fed *tars*. It is grown preferably in marginal lands. Preliminary studies have shown that ricebean can be grown in different types of soil including grey-, black-, yellow- or cream-coloured soils. However, red soil, which is moderate in fertility status, is considered best for ricebean cultivation (Khanal and Poudel, 2008). Based on indigenous knowledge of farmers, ricebean cultivation on highly fertile soil only promotes vegetative growth rather than an increment in yield. It does not perform well under shade or in north-facing aspects.

Cropping Patterns

In Nepal, farmers follow various cropping patterns for ricebean cultivation. Some of the common cropping patterns are discussed below: A. Mixed Cropping /Intercropping Mixed cropping is the most common cropping system followed by Nepalese farmers. It involves broadcasting of seeds. For proper intercropping, farmers dibble seeds in between maize plants. Farmers usually prefer varieties that mature in 140 to 150 days for intercropping with maize. In the case of relay cropping of maize and millet, ricebean is sown at the margins (*deel*) of the maize fi eld. B. Sole Cropping Some farmers grow ricebean in home gardens and in small pieces of land around the homestead as a sole crop. In this case, ricebean is produced for consumption within the family. Th e green tender beans are used as fresh vegetables. Landraces with long pods and bold grains are generally cultivated for this purpose. C. Planting on Rice Bunds

Planting small seeded determinate or semi-determinate ricebean on rice bunds is a very common practice in mid-western and farwestern regions of Nepal. Farmers sow the seeds on bunds, and when vegetative growth takes place, the plants are guided along the slopes of the terraces. D. Margins of Bari Land Planting ricebean at the margins of *bari*land (upland) is one of the most common practices in western midhills. Th e seeds are dibbled when maize plants are almost knee height. When vegetative growth is attained by the ricebean, they are guided along the slope of the *bari*land.

Sowing Method and Seed Rate

Attractive, well-formed grains free from pest infestation should be selected for sowing. Immature, shriveled and old grains should not be used as seeds. Pods for seeds are usually collected from the middle portion of the plant. Th e upper portion generally has smaller pods with poorly formed seeds. As ricebean has a problem of hard seeds, it is common practice among farmers to soak the seeds overnight (10-12 hours) before sowing. Th is isbeneficial not only to sort out hard seeds, but also to promote better seed germination. Seeds are either broadcasted or sown by dibbling. Usually, in case of intercropping with maize or other crops, it is broadcasted along with maize. However, if it is sown on rice bunds and in kitchen gardens, dibbling is more commonly used.

Package of Practices

Soil and Field Preparation

Rice bean can be grown on a wide range of soils, ranging from sandy loam to heavy soils, varying from dry to moist. However, like other pulses. saline and waterlogged soils are not suitable for this pulse also. Rice bean does not require a very fine tilth. It can perform well even in moderate land preparation. However, the type of tillage operation depends on the soil type and the time of sowing. It requires 2-3 deep ploughing followed by harrowing and levelling in heavy soil, while in light soil, it requires only one ploughing followed by harrowing and levelling. Clod-free uniform deep soil is necessary for establishing a good crop stand. Because of its adaptability to severe tropical conditions such as drought, high temperatures, humidity, poor soil, and preference for short days needed for flowering, rice bean is a valuable source of protein for both humans and livestock in the tropical lowlands. It will not succeed in waterlogged soil,

Sowing Time and Method

Rice bean is generally considered a summer growing legume. Therefore, it is mainly cultivated in the summer. However, it is also cultivated primarily on residual soil after paddy in the winter. It is sown in Kharif season with the onset of rains. Therefore, the optimal sowing time for this crop in hills is the month of May and in plains 1st fortnight of July. Sowing at optimum time gives the maximum yield and net profit. Late sowing lowers the seed yield and increases the chances of disease incidence. Seed drilling machine can sow seeds @ 8-10 kg/ha at 45-60 cm row spacing for vine types and 30-40 cm for erect types. Plant to plant distance at 15-20 cm should be maintained while sowing. This crop is also grown on a rotational schedule with other crops like maize, millets, and rice or as a kitchen garden crop for family use.

Varieties

Local: kehiir, orho, akethi, Longleng Local-1, Longleng Local-1, Developed line: PRR-1 (PRR 8801) and PRR-1 (PRR 8801) for hillyregions, RBL-1. RBL-6. RBL-35 and RBL-50 for plains, and BRS 1. Naini. 55

Manures and Fertilizers

Application of N: P: K @ 20-40-20 kg/ha is recommended for better yields. A basal dose of 50% N and a full dose of P and K should be applied at the time of sowing. The remaining N dose can be applied in two equal spilt as a top dressing, one at maximum vegetative phase and one at flowering stage. However, the rate of fertilizer application should be based on region-specific soil tests.

Intercultural Operation

Thinning plants should be done at 15-20 DAS to maintain the spacing and optimum population stands to get a better crop yield. When the plants are densely planted, there is competition for nutrients, moisture, space, and light. Overcrowding of plants sometimes becomes barren. Weeds are also a major problem during early growth stages. Slow initial growth of rice bean seedlings makes them poor competitors to many quick-growing weeds. Therefore, crop is susceptible to weed competition during the first 15-25 DAS. Pre-emergence application of pendimethalin @ 1.0 kg a.i.ha and one hand hoeing at 30-35 DAS or two hand hoeing at 20 and 40 DAS can be followed for the weed control.

Plant Protection

Diseases/Pests and their Management

Insect problem becomes serious during early growth stage and flowering time of rice

bean. The common enemy of pulse crops is the root-knotnematode. Planting resistant varieties, crop rotation, interplanting of marigold can reduce damage. Pest like Mylabris spp. is a severe problem during flowering time. They feed on flowers leading to poor pod production, thereby reducing crop yield. It is desirable to manually collect adults by nets and killing them in kerosinized water. The use of carbaryl 0.1% could control the Mylabris spp.

Yellow bean mosaic

Virus particles are transmitted through aphids. The virus infected plant shows the symptom of mottling, yellowing and malformation of leaves and pods. Infected plant may be stunted and bunchy, seeds may be aborted, smaller or malformed, and yields may be reduced by up to 80-100%, depending on the plant stage of growth at the time of infection.

Management

The mosaic control is obtained by using certified virus-free seed and planting virus-resistant rice bean varieties. Crop rotation with non-legume crops reduces severity of disease. Apply NSKE 5% (neem seed kernel2 ml/l of water or dimethoate 30 EC @ 650 ml/ha in 600 lit water. extract) to control the aphids. Young crop may be applied with chlorpyriphos

Harvesting and Yield

The time and method of harvesting depend on nature of maturity of the crop. Pods tend to shatter when left on the plants for a long time, therefore, harvest the crops before all the pods in the vine mature to save the seed loss due to pod shattering. Depending upon genotypes, it starts blooming in September and October as the day length is reduced and pods mature in November-December. In varieties exhibiting synchronous or cutting entire plant at ground as and maturity, harvesting is done by uprooting level when the plants show about 90% maturity. In types which do not have synchronous maturity, pods are harvested by hand picking when it matures. This method of harvesting is done in the morning or evening hours to avoid shattering losses while handling pods. The harvested crop is then dried in the sun, and then well-dried pods are threshed by various methods depending upon the quantity harvested. A small amount of grain is threshed out by beating the dried pods with a bamboo stick which is the most common when there is little production. For a larger amount of beans, threshing is done by the trampling of the draft animal The seed is then winnowed and cleaned, and it can yield about 8-15 q/ha in hilly region and about 11-16 q/ha in plains (Acharya 2008).

Storage

Seeds are dried for 1-2 days before they are stored at moisture content level 8-10%. A small change in seed moisture content has a large effect on storage life of seeds. Any storage should be thoroughly cleaned before grain is brought in to avoid any storage loss due to storage pests. It is necessary to give proper care because grain legumes are more prone to insects in storage than their counter cereals.

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A BIRD'S EYE VIEW ON RNA WORLD HYPOSTHESIS

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Introduction

The **RNA World Hypothesis** is a theory in biochemistry and molecular biology that suggests that early life on Earth may have relied on RNA molecules both to store genetic information and catalyze chemical reactions, before DNA and proteins became the central components of life as we know it today. This hypothesis proposes that RNA played a dual role in early life, functioning both as the genetic material (like DNA does today) and as a catalyst for chemical reactions (like proteins do in modern cells).

RNA is not just a genetic carrier; its functions are wide-ranging and include:

- Protein synthesis (mRNA, tRNA, rRNA)
- Catalysis (ribozymes)
- Gene regulation (miRNA, siRNA, lncRNA)
- Telomere maintenance (telomerase RNA)
- Splicing of pre-mRNA (snRNA)
- RNA editing
- Structural roles in cells
- Serving as viral genomes
- Acting as molecular switches
- Contributing to the immune response

The diverse roles of RNA in cellular processes highlight its importance beyond just serving as a template for protein synthesis and underscore its central role in life's biochemistry.

Key Points about the RNA World Hypothesis:

1. **Self-replicating RNA**: The hypothesis suggests that RNA molecules could have been capable of self-replication, meaning they could duplicate themselves without the help of proteins. This would have allowed them to evolve over time.
2. **Catalysis by RNA**: RNA molecules, known as **ribozymes**, have the ability to catalyze chemical reactions, similar to how proteins work as enzymes today. This would have allowed RNA to drive chemical processes necessary for life.
3. **Preceding DNA and Proteins**: According to the hypothesis, RNA preceded DNA and proteins in the origin of life. This is because RNA has the unique ability to both store information and catalyze reactions, which would have made it central to early life forms.
4. **Evolution of DNA and Proteins**: Over time, the theory suggests that DNA took over the role of storing genetic information because it is more stable than RNA. Proteins, which are more efficient at catalyzing reactions, gradually took over many of the functions once performed by RNA.

Evidence Supporting the RNA World Hypothesis:

- **Ribozymes**: The discovery of ribozymes (RNA molecules that can catalyze biochemical reactions) supports the idea that RNA could have had catalytic properties in early life forms.
- **RNA's Structure**: RNA's ability to store genetic information, through sequences of nucleotides (adenine, uracil, cytosine and guanine), and its structural similarity to DNA, lends credence to the idea that it could have served both as a genetic material and a catalyst.
- **Amino Acid-Generating RNA Sequences**: Some RNA sequences can bind and catalyze reactions that help form amino acids, the building blocks of proteins, which points to a possible connection between early RNA-based life and later protein-based life.

RNA plays a crucial role in many biological processes beyond just carrying genetic information. Its versatility and adaptability make it indispensable in modern cellular biology. Here are the **varied functions of RNA**:

1. Genetic Information Carrier (mRNA)

- **Messenger RNA (mRNA)** is the RNA molecule that carries genetic information from DNA to the ribosome, where proteins are synthesized. This process is known as **transcription** (DNA to RNA) and **translation** (RNA to protein).
- mRNA acts as a temporary copy of a gene's instructions, allowing the genetic code to be translated into functional proteins.

2. Protein Synthesis (tRNA and rRNA)

- **Transfer RNA (tRNA)**: tRNA molecules carry amino acids to the ribosome during translation. Each tRNA has an anticodon that pairs with a corresponding codon on the mRNA, ensuring the correct amino acid is added to the growing polypeptide chain.
- **Ribosomal RNA (rRNA)**: rRNA is a structural and functional component of ribosomes. Ribosomes are the molecular machines that read mRNA and assemble the corresponding amino acids into proteins. rRNA also catalyzes the formation of peptide bonds between amino acids during protein synthesis.

3. Catalysis (Ribozymes)

- **Ribozymes** are RNA molecules that can catalyze biochemical reactions, much like protein enzymes. This function is one of the key features of the **RNA World Hypothesis**, suggesting that early life could have relied on RNA for both information storage and catalysis.
- Examples include **self-splicing RNA**, which removes introns (non-coding regions) from mRNA, and **RNase P**, which processes precursor tRNA molecules.

4. Gene Regulation

- RNA is involved in regulating gene expression at various stages. Some RNA molecules control the **transcription** of genes, while others regulate the **translation** of mRNA into proteins.
- **MicroRNA (miRNA)** and **small interfering RNA (siRNA)** are types of small RNA molecules that can bind to mRNA molecules, either degrading them or preventing their translation, thereby controlling gene expression. This process is known as **RNA interference (RNAi)**.
- **Long non-coding RNA (lncRNA)**: These RNAs do not code for proteins but play a role in regulating gene expression, chromatin remodeling, and other cellular processes.

5. Telomere Maintenance (Telomerase RNA)

- **Telomerase RNA** is a component of the telomerase enzyme, which helps maintain the length of telomeres, the protective caps at the ends of chromosomes. Telomerase uses an RNA template to extend the telomeres, which is important for maintaining chromosome integrity during cell division and preventing premature cell aging.

6. Splicing of Pre-mRNA (snRNA)

- **Small nuclear RNA (snRNA)** is involved in the process of **RNA splicing**, which removes non-coding regions (introns) from the precursor mRNA (pre-mRNA) and joins the remaining coding regions (exons) together. This process is carried out by **spliceosomes**, which are complexes of snRNAs and protein molecules.
- This process is essential for generating mature, functional mRNA that can be translated into proteins.

7. RNA Editing

- RNA editing involves post-transcriptional modifications to the RNA molecule, such as the insertion, deletion, or substitution of nucleotides. This allows the cell to diversify the proteins it produces from a single gene.
- An example is **Adenosine-to-inosine editing** by the enzyme **ADAR**, which alters the RNA sequence and can affect protein function or RNA stability.

8. RNA as a Structural Molecule

- RNA can have structural roles within the cell. For example, the ribosome (composed of rRNA and proteins) has a critical structural function in facilitating protein synthesis.
- Other RNA molecules can have specific structural roles within cellular organelles, such as the **nucleus** and **mitochondria**, contributing to the overall structure and function of these regions.

9. Viral Genomes

- Some viruses, particularly **RNA viruses**, use RNA as their genetic material instead of DNA. This includes well-known viruses like influenza, HIV, and the SARS-CoV-2 virus. In these viruses, RNA stores genetic information and directs the assembly of new viral particles.
- In some cases, the RNA of the virus can also encode enzymes (like **reverse transcriptase** in retroviruses) that are necessary for the virus's life cycle.

10. RNA as a Molecular Switch

- RNA molecules can act as molecular switches in response to cellular conditions, controlling gene expression or protein activity in a highly dynamic manner.
- **Riboswitches** are RNA sequences that change their shape upon binding to small molecules, enabling them to regulate gene expression, often by influencing transcription or translation.

11. RNA in the Immune Response

- Certain types of RNA, such as **long non-coding RNAs**, are involved in the immune response. They can help detect pathogens and trigger immune signaling pathways, leading to the activation of immune responses.
- Additionally, **RNA sensors** in cells can recognize viral RNA, leading to antiviral responses through pathways like the **RNA interference (RNAi)** pathway.

The **RNA World Hypothesis** is critically important in the study of the origins of life for several reasons, offering profound insights into how life may have emerged on Earth. Here are some of the key ways in which the RNA World Hypothesis is important:

1. Understanding the Origin of Life

The RNA World Hypothesis provides a potential pathway for the emergence of life on Earth. It suggests that life could have started with simple molecules that gradually became more complex over time. The idea that RNA could serve both as genetic material and as a catalyst for chemical reactions helps us to explain how the first self-replicating systems could have emerged without the need for complex proteins or DNA, which are central to life today.

2. Explaining the Dual Function of Early Biomolecules

One of the most important aspects of the RNA World Hypothesis is that it proposes RNA could have both stored genetic information and catalyzed chemical reactions. This dual function is crucial because it would have allowed for a simpler, more efficient system in the early stages of life, before DNA and proteins took over specialized roles. This idea suggests that early life forms were much simpler than the complex systems we observe today, which is an important stepping stone in understanding how life could have originated.

3. Connection to Modern Biology

Many aspects of modern biology, particularly molecular biology, still rely heavily on RNA:

- **RNA's role in protein synthesis**: In modern cells, RNA is central to the process of translating genetic information from DNA into proteins (through mRNA, tRNA, and ribosomal RNA).
- **Ribozymes**: The discovery of RNA molecules that can catalyze reactions (ribozymes) supports the idea that RNA could have had a catalytic role in the origin of life, similar to how proteins act as enzymes today.
- **RNA in regulatory roles**: RNA also plays critical roles in gene regulation, and some scientists believe that the study of these RNA functions can shed light on how life transitioned from an RNA-based world to the DNA-protein world we are familiar with.

4. Insight into Early Evolution

The RNA World Hypothesis implies that early life may have evolved in a simpler, more flexible environment. RNA molecules can evolve and adapt more readily than DNA because RNA has a higher mutability, and thus could have played a significant role in the initial diversification of life. The theory suggests that early evolution was driven by RNA molecules that evolved into more complex systems as life progressed. This provides a simpler view of the evolutionary path that could have led to modern, more complex organisms.

5. Implications for the Search for Extraterrestrial Life

The RNA World Hypothesis also has important implications for astrobiology—the study of life in the universe. If life on Earth could have originated through an RNA-based system, it suggests that other planets with similar conditions might also support RNA-based life forms. This broadens the scope for potential life forms that scientists might look for in other parts of the universe. The idea that RNA could form and catalyze reactions on its own increases the possibility that life could emerge on other planets with conditions suitable for the chemistry of RNA.

6. Evolution of Complexity

The RNA World Hypothesis also speaks to the evolution of biological complexity. It suggests that life started with relatively simple molecules that could both store information and carry out functions, and as the need for greater efficiency grew, more specialized systems (DNA and proteins) emerged. This helps us understand how the incredibly complex molecular machinery in modern cells (which involve DNA, proteins, lipids, and other molecules) might have evolved step by step from simpler RNA-based systems.

7. Biochemical and Synthetic Biology

From a scientific and practical standpoint, the RNA World Hypothesis has inspired much of the field of synthetic biology and research into the origins of life. Understanding how RNA might have emerged from simple molecules has implications for designing artificial life forms or building synthetic systems that can replicate themselves or evolve. This also leads to a deeper understanding of biochemistry, as scientists explore the properties of RNA and how its structure and function could have played a role in life's origins.

Challenges and Unsolved Questions:

- **How did the first self-replicating RNA molecules form?** There is still much uncertainty about how simple molecules could have formed self-replicating RNA strands, especially considering the complexity of RNA molecules.
- **The transition to DNA and proteins**: Understanding how and why RNA-based life forms evolved into the DNA-protein-based systems we have today remains a major open question in evolutionary biology.

Summary

The RNA World Hypothesis is crucial for understanding how life could have originated from simple molecules and evolved into the complex biological systems we see today. It connects modern molecular biology, offers insights into early evolutionary processes, and holds potential for guiding future research into the origin of life and the possibility of extraterrestrial life.

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ROLE OF BENTHOS IN BIOTURBATION AND RECLAMATION

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Introduction

Benthos, the community of organisms inhabiting the bottom substrates of aquatic ecosystems, play a pivotal role in ecosystem functioning, particularly through the process of bioturbation. Bioturbation refers to the disturbance and reworking of sediments by benthic organisms such as polychaete worms, bivalves, crustaceans, and sea cucumbers. This activity enhances sediment oxygenation, promotes nutrient cycling, and supports the microbial degradation of organic matter and pollutants. In reclamation of degraded or polluted aquatic environments, bioturbation by benthos aids in restoring sediment quality and improving habitat conditions. These organisms also contribute to the stabilization of sediments and support trophic interactions necessary for ecosystem recovery. Moreover, benthic community structure is often used as a bioindicator of environmental health, making them essential in monitoring and assessing restoration success. Understanding the ecological roles of benthos in sediment dynamics and bioremediation offers valuable insight for sustainable aquaculture, wetland restoration, and integrated coastal management practices.

Introduction

Benthos refers to the diverse community of organisms that live on, in, or near the bottom of aquatic environments, including oceans, estuaries, rivers, lakes, and ponds. The word "benthos" is derived from the Greek word *"bathos"*, meaning depth.These organisms inhabit the **benthic zone**, which includes the sediment surface and sub-surface layers. Unlike pelagic organisms (which live in the water column), benthic organisms are closely associated with the sediment and substrate of aquatic ecosystems.Includes **macrofauna** (e.g., worms, mollusks,

crustaceans), **meiofauna**, and **microbenthos** (e.g., bacteria, fungi).These organisms play crucial ecological roles, particularly in **bioturbation** and **sediment reclamation**.

What is Bioturbation?

Bioturbation is the process by which organisms living within sediments disturb, rework, and transport sediment particles through their feeding, burrowing, and movement activities. This phenomenon occurs in both marine and freshwater environments and plays a vital role in shaping the physical and chemical properties of the sediment-water interface.

The primary agents of bioturbation are benthic macrofauna such as polychaete worms, bivalves, crustaceans, echinoderms, and some burrowing fish. These organisms significantly influence sediment structure by altering its porosity, aeration, and nutrient distribution. Through their activity, they create complex microhabitats that support microbial life and enhance the degradation of organic matter.

This activity changes:

- **Sediment structure**
- **Oxygen penetration**
- **Nutrient distribution**

Key Benthos Involved in Bioturbation

- **Polychaete worms** (e.g., *Nereis, Capitella*): Deep burrowers and active mixers.
- **Bivalves** (e.g., clams, mussels): Pump water through sediments, increasing aeration.
- **Crustaceans** (e.g., ghost shrimp, amphipods): Create complex burrow systems.
- **Sea cucumbers**: Bioturbators that ingest large volumes of sediment, aiding in nutrient recycling.

Functions and Benefits of Bioturbation

- **Oxygenation of Sediments**:
  - Enhances aerobic microbial activity, aiding in organic matter decomposition.
- **Nutrient Cycling**:
  - Increases availability of nitrogen, phosphorus, and trace elements.
- **Contaminant Degradation**:
  - Promotes natural attenuation of pollutants by stimulating microbial communities.
- **Sediment Texture Improvement**:
  - Loosens compacted sediments, promoting healthier benthic habitats.

Role in Reclamation of Degraded Aquatic Systems

- **Reclamation** refers to restoring degraded or polluted water bodies to functional ecosystems.
- **Natural Bioremediation Agents**:
    - Bioturbating benthos stimulate microbial communities that degrade organic and inorganic pollutants.
- **Improved Sediment Quality**:
    - Bioturbation reduces sediment toxicity and improves physicochemical characteristics.
- **Restoration of Trophic Interactions**:
    - Presence of healthy benthos supports higher trophic levels (e.g., fish), aiding in ecosystem recovery.
- **Stabilization of Sediment**:
    - Some benthic species contribute to biofilm formation or excrete binding substances that stabilize sediment.

Applications in Aquaculture and Coastal Management

- **Integrated Multi-Trophic Aquaculture (IMTA)**:
    - Using benthos like sea cucumbers or bivalves to recycle organic waste.
- **Constructed Wetlands and Aquaculture Pond Bottom Management**:
    - Introducing beneficial benthic fauna can enhance bottom health and prevent anaerobic conditions.
- **Bioindicators of Recovery**:
    - Benthic community diversity and abundance are often used to monitor reclamation success.

Challenges and Considerations

- **Sensitivity to Pollution**:
    - Heavy metal or organic pollution may kill benthic fauna, halting bioturbation.
- **Species-Specific Effects**:
    - Not all benthos have the same functional roles; ecosystem management requires specific species selection.

- **Invasive Benthic Species**:
    - Some species may disrupt local sediment processes or outcompete natives.

Conclusion

Benthos plays an indispensable role in maintaining the health and functionality of aquatic ecosystems through the process of bioturbation. By burrowing, feeding, and moving within sediments, benthic organisms significantly alter the physical and chemical properties of the sediment, enhancing oxygen penetration, nutrient cycling, and microbial activity. These processes are fundamental to the natural reclamation of degraded or polluted aquatic environments, making benthic fauna key players in bioremediation and ecosystem restoration. Furthermore, their presence and activity are strong indicators of environmental quality and recovery. Understanding and harnessing the ecological services provided by benthos can greatly improve sustainable aquaculture practices, habitat restoration efforts, and integrated aquatic resource management. Therefore, the protection and enhancement of benthic communities should be a priority in environmental and water quality management strategies.

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SMART FISHERMEN: HOW DIGITAL TOOLS ARE CHANGING LIVES ALONG THE COAST

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Abstract

The traditional knowledge of coastal fishermen is now being enhanced by modern digital tools that provide real-time data, market access, and safety alerts at their fingertips. From mobile applications that forecast weather conditions to GPS-enabled fish finders and e-commerce platforms, digital technologies are empowering fisherfolk to make informed decisions, reduce operational risks, and increase their incomes. This article highlights key digital interventions transforming marine livelihoods, enhancing safety at sea, and supporting sustainable fisheries management along the Indian coastline.

Keywords: Smart fishermen, mobile apps, GPS, e-marketing, vessel tracking, fisheries extension

Introduction

Fishing communities along India's vast coastline have always relied on their intuition, experience, and word-of-mouth advice to venture into the seas. However, with growing challenges such as climate change, fluctuating fish catches, and market uncertainties, traditional methods alone are no longer sufficient. The integration of Information and Communication Technologies (ICTs) in fisheries extension has become a game-changer offering real-time solutions that are affordable, accessible, and scalable. This article explores how digital tools are reshaping the lives of India's coastal fisherfolk, empowering them to be smarter, safer, and more sustainable.

Mobile Apps for Weather and Sea Condition Forecasting

Fishermen now use **mobile apps** like *MEGHDOOT*, *Sagar Vani*, and *Fisher Friend* to

receive timely weather updates, wave heights, wind direction, and ocean current information. These tools help reduce risks during fishing operations and have become crucial for planning sea trips. For example, *Fisher Friend Mobile App* developed by MSSRF delivers location-specific advisory in regional languages (Kumar et al., 2021).

FIG1: FFMA mobile

GPS and Fish Finder Technologies

With handheld **GPS devices** and **echosounders**, fishermen can now mark productive fishing zones (PFZs), trace return routes, and avoid dangerous areas. Indian National Centre for Ocean Information Services (INCOIS) provides **PFZ forecasts** through SMS and app-based platforms, increasing fuel efficiency and catch rates by guiding fishermen to regions rich in fish aggregation (INCOIS, 2024).

Digital Marketing and e-Commerce in Fisheries

E-marketing platforms like *e-SANTA* and *MatsyaSetu* are connecting fishers and aquapreneurs directly with consumers, retailers, and exporters eliminating middlemen. These digital platforms enhance price transparency, reduce post-harvest losses, and allow producers to bargain better (FAO, 2023). With smartphone penetration rising, even small-scale fisherwomen are using WhatsApp groups to sell fish locally.

FIG2: Matsya Setu mobile app

Satellite-Based Vessel Tracking Systems (VTS)

The Government of India is actively promoting the use of satellite-based vessel tracking systems (VTS) for deep-sea fishing boats to enhance safety and surveillance in marine fisheries. These advanced systems enable real-time tracking of the location and movement of fishing vessels, which is particularly crucial in case of emergencies or distress at sea. By allowing authorities to quickly locate and assist fishers during mishaps such as storms, engine failure, or accidents, VTS has become a critical safety tool that helps save lives.

In addition to improving rescue operations, vessel tracking systems also play a key role in regulating fishing activities. They help monitor fishing zones, discourage unauthorized entry into restricted areas, and significantly reduce illegal, unreported, and unregulated (IUU) fishing practices. Overall, the initiative is strengthening marine governance while ensuring better protection for the livelihoods and lives of fishers (DAHD, 2023).

Fisheries Extension through Digital Platforms

Digital extension has significantly expanded the outreach of training and advisory services in the fisheries sector. Platforms such as YouTube channels, Facebook pages, and specialized mobile applications are increasingly used to deliver timely and relevant information to fishers and aquafarmers. One notable example is the *MatsyaSetu* app developed by ICAR-CIFE, which provides access to training videos, farming modules, e-learning content, and direct expert consultations in regional languages. These tools have made extension services more accessible, especially for youth and remote communities.

In addition, social media applications like WhatsApp are being actively used by fisheries officers to form community groups. These groups allow officers to instantly share vital information, including disease outbreak alerts, availability of quality inputs (like seed and feed), market rates, and updates on government schemes and subsidies. This real-time, two-way communication ensures that fishers are well-informed and can make quick decisions, thereby improving their productivity and resilience (Singh et al., 2022).

Conclusions

Digital tools are revolutionizing India's fisheries sector by improving livelihoods, safety, and sustainability. The once-isolated fisher now has access to real-time ocean data, markets, and expert knowledge through mobile phones and digital platforms. As technology continues to evolve, fisheries extension must ensure that these innovations are inclusive, affordable, and

tailored to the needs of both marine and inland fishing communities. Empowering "smart fishermen" is not just about tools—it's about creating a resilient and informed coastal population that can thrive in changing times.

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WATER POLLUTION: THE CRISIS WE CAN'T AFFORD TO IGNORE

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Introduction

Have you ever stood beside a river and seen plastic bags caught in branches or noticed foam floating on the water's surface? What used to be clean and full of life now looks murky and lifeless. This is water pollution—and it's happening everywhere, even in the water we drink and the food we eat. Every time we dump waste, pour chemicals down the drain, or let plastic float away, we harm our rivers, lakes, oceans, and underground water. If we want clean water for ourselves and future generations, we must understand this growing problem and act urgently.

What Is Water Pollution?

Water pollution occurs when harmful substances contaminate natural water bodies such as rivers, lakes, oceans, and groundwater. These pollutants include garbage, oil, industrial waste, chemicals, plastics, and untreated sewage. When these substances enter water sources, they make the water unsafe for drinking, cooking, farming, fishing, and swimming. Clear, healthy water becomes cloudy, smelly, and full of bacteria, viruses, or toxins that can seriously affect the health of both humans and animals.

According to recent studies, more than 70% of India's surface water is now polluted, making most of our rivers and lakes unsafe for use without treatment. This alarming statistic highlights that the crisis is not only environmental—it is also social, economic, and a significant public health concern.

Major Sources of Water Pollution

Although water pollution has many causes, four major sources are particularly concerning:

1. **Domestic Waste (Sewage)** Every day, wastewater from our homes—dishwater, laundry water, bathing water, and toilet waste—is discharged into nearby rivers and drains. This waste, often termed sewage, frequently contains soap, detergents, food particles, and harmful pathogens (disease-causing germs) that significantly degrade water quality and spread diseases.
2. **Industrial Discharge** Many industries release untreated or poorly treated wastewater (effluents) directly into natural water bodies. These effluents are often laden with highly toxic heavy metals like lead, mercury, arsenic, and chromium, as well as organic pollutants and acids. These substances are bioaccumulative, meaning they build up in aquatic life and, through the food chain, ultimately pose severe health risks to humans who consume contaminated fish and seafood.
3. **Agricultural Runoff** The widespread use of chemical fertilizers, pesticides, and herbicides in modern agriculture contributes significantly to water pollution. During rains or irrigation, these chemicals are washed from fields into rivers, lakes, and even groundwater. This runoff leads to eutrophication (excessive nutrient build-up) in water bodies, causing explosive growth of algae (algal blooms). These blooms deplete oxygen levels when they decompose, leading to the death of fish and other aquatic organisms, severely damaging ecosystems.
4. **Plastic and Solid Waste** Plastics, wrappers, bottles, packaging materials, and other non-biodegradable garbage improperly disposed of on roadsides or near drains often end up in water bodies. These materials not only block drains and exacerbate flooding but also pose direct threats to aquatic life by entanglement and ingestion. Over time, plastics break down into microplastics, tiny fragments that are ingested by aquatic organisms and subsequently enter the human food chain, with largely unknown long-term health implications.

Effects of Water Pollution

The impacts of water pollution are wide-ranging and severe, affecting every facet of life:

- **Health Hazards:** Polluted water is a breeding ground for pathogens that cause widespread diseases such as cholera, typhoid, hepatitis, dysentery, and diarrhea. Long-

term exposure to chemical pollutants can lead to chronic illnesses including various forms of cancer, birth defects, neurological disorders, and severe damage to vital organs like the liver and kidneys.

- **Loss of Biodiversity:** Aquatic ecosystems are incredibly fragile. Pollution reduces dissolved oxygen levels, introduces toxins, and alters water chemistry, leading to the death of sensitive species, disruption of food chains, and ultimately the collapse of entire aquatic ecosystems. This loss of biodiversity has irreversible consequences for the planet's natural balance.
- **Food Contamination:** Crops irrigated with polluted water absorb harmful chemicals and heavy metals, which then directly enter the human food system. Similarly, livestock consuming contaminated water or feed can transfer these toxins into meat and dairy products.
- **Economic Losses:** Industries heavily reliant on clean water, such as fishing, aquaculture, tourism, and water transport, suffer significant economic losses. This impacts the livelihoods of millions and costs communities vast sums in remediation efforts and lost revenue each year.
- **Groundwater Contamination:** The leaching of pollutants from landfills, industrial waste, and agricultural chemicals into groundwater aquifers is a silent but pervasive threat. This reduces the availability of safe drinking water in both rural and urban areas, forcing communities to rely on expensive and energy-intensive treatment processes or alternative sources.

Case Studies: Lessons from India and Beyond

Several real-world examples tragically illustrate the seriousness of water pollution:

- **The Ganga River (India):** Once revered for its purity and spiritual significance, the Ganga now carries an enormous burden of industrial effluents and untreated municipal waste across its vast course. Despite significant government clean-up efforts (such as the Namami Gange program), large stretches remain highly polluted and unsafe for direct human use. As of early 2025, a large proportion of sewage still goes untreated, and while some areas show reduced pollution, high levels of disease-causing bacteria (faecal coliforms) and organic pollution persist. For instance, in January 2025, faecal coliform

levels at Sangam Ghat were reported to be four times the safe limit, highlighting the ongoing challenge.

- **The Yamuna River (Delhi, India):** The Yamuna, particularly in its stretch through Delhi, is notorious for turning black and toxic, especially after religious festivals due to the mass immersion of idols and rampant discharge of untreated urban sewage. This has severely impacted the river's ecological health and the quality of life for communities along its banks. Recent reports from July 2025 indicate a surge in pollution levels, with fecal coliform levels at ITO reaching extremely high levels (9,200,000 MPN/100ml), thousands of times the acceptable limit for outdoor bathing. Dissolved oxygen levels have plummeted, reaching zero in some downstream stretches. A coordinated inter-state mission has been launched, but the situation remains critical.
- **Lake Erie (North America):** A poignant example from beyond India, Lake Erie faced a massive and recurrent toxic algae bloom crisis due to excessive fertilizer runoff from agricultural lands in the surrounding areas. These blooms poisoned drinking water for hundreds of thousands of residents, led to large-scale fish kills, and severely disrupted the lake's ecosystem and recreational activities. As of July 2025, Lake Erie continues to experience harmful algal blooms annually, primarily caused by excess phosphorus. Federal scientists predicted a mild to moderate bloom for western Lake Erie in the summer of 2025. While efforts are ongoing to reduce nutrient supply, concerns remain about funding for these initiatives and the increasing duration and toxicity of the blooms due to warmer water temperatures.

These examples emphatically show that even the most iconic and vital water bodies are vulnerable without stringent regulations, robust enforcement, and widespread public cooperation.

Solutions and What Can Be Done

While the problem is severe and complex, it is not unsolvable. With concerted and collaborative efforts from governments, industries, communities, and individuals, we can indeed reverse the damage and secure our water future.

Government and Policy-Level Actions:

- **Enforce Strict Laws and Regulations:** Implement and rigorously enforce laws requiring all domestic and industrial wastewater to be treated to prescribed standards before discharge. Penalties for non-compliance must be significant enough to act as a deterrent.

- **Invest in Infrastructure:** Prioritize the construction, modernization, and efficient operation of sewage treatment plants (STPs) and common effluent treatment plants (CETPs) in all urban and rural areas. This includes developing decentralized treatment solutions.
- **Monitor and Regulate Industrial Effluents:** Establish continuous monitoring systems for industrial discharges and penalize illegal dumping or inadequate treatment stringently. Promote cleaner production technologies and waste minimization at the source.
- **Promote Sustainable Agriculture:** Encourage and incentivize the widespread adoption of bio-fertilizers, organic farming practices, precision agriculture, and integrated pest management to significantly reduce chemical runoff into water bodies.
- **Protect Wetlands and Riparian Zones:** Implement policies to protect and restore natural wetlands and riparian buffer zones, which act as natural filters for pollutants and support biodiversity.

Community and NGO-Level Actions:

- **Organize Clean-up Drives:** Regularly organize and participate in clean-up drives along riverbanks, lakes, beaches, and other water bodies. These efforts not only remove visible pollution but also raise awareness.
- **Conduct Awareness Campaigns:** Launch extensive awareness campaigns through schools, colleges, community centers, social media, and local events to educate citizens about the causes, effects, and solutions to water pollution.
- **Develop Community-Level Solutions:** Support and implement community-based initiatives for rainwater harvesting, greywater recycling, and local wastewater treatment to reduce reliance on centralized systems and promote self-sufficiency.
- **Advocate for Policy Change:** Actively engage with local authorities and policymakers to advocate for stronger environmental laws, better infrastructure, and transparent governance in water management.

Individual Actions:

- **Responsible Waste Disposal:** Never pour oil, grease, paint, chemicals, expired medicines, or non-biodegradable waste down household drains or toilets. Dispose of them properly according to local guidelines.

- **Reduce Plastic Consumption:** Drastically reduce single-use plastic by carrying reusable cloth bags, water bottles, coffee cups, and food containers. Support businesses that minimize plastic packaging.
- **Use Eco-Friendly Products:** Opt for biodegradable and eco-friendly cleaning products, detergents, and personal care items that contain fewer harmful chemicals.
- **Conserve Water:** Fix leaky taps and pipes promptly. Practice water conservation in daily activities, such as taking shorter showers, turning off the tap while brushing teeth, and using water-efficient appliances. Collect rainwater for gardening or other non-potable household uses.
- **Support Water Conservation Efforts:** Actively support and participate in local water conservation efforts, citizen science programs, and environmental organizations dedicated to protecting water resources.
- **Be a Conscious Consumer:** Be aware of the environmental footprint of the products you buy, especially those from industries known for high water usage or pollution.

Conclusion

Clean water is not merely a commodity; it is a basic human right and the fundamental pillar of all life on Earth. Water pollution threatens not only our environment but also our health, economy, and the very future of coming generations. If we continue to disregard the health of our lakes, rivers, and oceans, we risk losing access to one of the most essential elements of life, leading to irreversible consequences. However, with heightened awareness, decisive action, and unwavering commitment from every section of society—governments, industries, communities, and individuals—we can collectively restore our invaluable water bodies and ensure a safer, healthier, and more sustainable world for all.

Every drop of water matters. Every step we take counts. Let’s act now for a cleaner tomorrow.

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UNIQUE SELLING PROPOSITION

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Abstract

Current market characterized by an overwhelming variety of products and services, a company's ability to differentiate itself from competitors has become increasingly important. Differentiation is a vital requirement for survival in a highly competitive environment where consumers face an abundance of choices. With the continuous growth and evolution of the market, businesses must identify and communicate distinctive attributes of their products that resonate directly with their target audience. A USP is defined as a distinct and compelling statement that encapsulates the unique benefits or features of a product or service, setting it apart from competitors in a way that connects with consumers. The USP acts as a strategic tool linking a company's marketing efforts to its core strengths and customer needs. Brands can successfully express their distinctiveness via the USP, ensuring they stand out in a crowded market.

Unique Selling Proposition (USP)

A Unique Selling Proposition is a crucial idea in marketing that emphasizes distinct characteristic or advantage that distinguishes a product or service from its rivals. This change could be due to factors like improved quality, lower costs and distinguishing features. USP is to effectively convey this feature to intended audience, establishing a unique identity that connects with consumers and encourages them to select particular brand over its competitors. With a variety of choices, businesses must distinguish themselves while persuading potential customers that their product is the superior choice.

A defined USP is crucial as it offers consumers a distinct and persuasive reason to choose one brand instead of its rivals. Lacking a distinct unique selling proposition, a brand may blend with numerous comparable products, causing price to be the sole differentiating element. An USP enables a brand to set higher prices, cultivate customer loyalty and attain sustained market success through the creation of a distinctive and appealing brand identity.

Key Elements of Unique Selling Proposition

A compelling Unique Selling Proposition (USP) is a key involve that defines a brand or product from its competitors. An USP, isolation suggests more than just being distinctive and additionally implies be significantly different in a way that resonates with the intended loyalty. An USP should emphasize the unique characteristics or benefits of a product that competitors cannot provide a strong competitive advantage. This exclusion may result from colorful qualities viz., modern technology, distinguishing features, high quality or a creative approach to client service.

The key element, the USP must meet a real need or provide a solution to a problem that competitor's products do not address the brand as the preferred alternative for consumers. A unique selling proposal that fails to resonate with the target loyalty, its novelty, will not produce the desired outcomes. It is vital for firms have a thorough awareness of their target audience, including their issues, preferences and provocations.

This intelligence enables brands to develop a unique selling proposition that shows what distinguishes their product or service and defines the importance of that distinction to the client. If prospective buyers prioritize battery life over camera quality, this selling point may become trivial and fail to engage the intended followers.

A unique selling proposition needs to be credible and supported by data that validates the claims it makes in order to be successful. The dependability of a USP is essential for building confidence and convincing potential buyers that the product or service will live up to its promises as consumers become more dubious of marketing claims.

Process of Developing USP

The first step in USP process is to identify the target audience. The target audience is essential because the USP must correspond with the specific needs, desires and preferences of that group. A thorough assessment of the target audience necessitates segmenting the market based on demographic, psychographic and behavioral characteristics. This segmentation allows

marketers to pinpoint the exact group of consumers who are most apt to benefit from the product or service.

The next step in developing a USP is to analyze the competition. This necessitates conducting a thorough competitive analysis to understand the strengths and weaknesses of different products or services offered in the market. By examining the existing USPs of competitors, a business can identify areas or opportunities where its product can shine. This procedure not only emphasizes competitor's strengths or weaknesses in their value.

A thorough competitor analysis helps in understanding market trends, customer preferences and potential threats, enabling a business to strategically place its unique selling proposition. Emphasizing the distinct advantages of a product or service is essential for crafting a compelling Unique Selling Proposition (USP). This phase focuses on recognizing and expressing what differentiates the product or service placing its superiority or uniqueness in comparison to competitors within the market. The unique benefits may pertain to the product's efficiency, design and ease of use or any other characteristic that delivers real value to the customer.

The last stage in creating a USP is to evaluate and enhance it according to market responses. The most extensively researched and carefully developed USP can gain from verification through practical implementation. This involves assessing the USP with a selection of the target audience to measure their responses and collect input. Different techniques can be employed for evaluation, including focus groups, questionnaires or even experimental marketing strategies. To enhancing the USP, offering clarity on how effectively the message resonates with the audience and its ability to convey the intended value proposition. This ongoing cycle of evaluation and improvement guarantees that the USP adapts to shifting market demands and stays pertinent through time.

Integrating USP into Marketing Strategies

Integrating a Unique selling proposition into marketing approaches ensures that the specific value of a product or service influences every aspect of brand communication. Central to this integration is brand messaging, acting as the narrative structure that enables a business to convey its USP to the market.

Brand messaging involves the uniform conveyance of the USP across all communication platforms, such as advertising, public relations, social media and customer

interactions. The aim is to establish a unified brand identity that highlights the distinct advantages of the product or service in each engagement. This uniformity in communication enhances brand worth by aiding in establishing and strengthening the brand's standing in consumers' perceptions.

Advertising is crucial in the USP, serving as the main channel through which a brand engages with its audience. In marketing campaigns, the unique selling proposition should serve as the primary element guiding the creative strategy and communication. Successful advertising communicates the unique selling proposition effectively and establishes an emotional connection with the intended audience.

A unique USP forms the basis of the sales strategy, directing how sales teams engage with prospective customers and present the product or service. The sales strategy synchronizing with the unique selling proposition guarantees that businesses provide sales pitches that are compelling and consistent with the brand's overall messaging. This requires educating sales teams to grasp and convey the USP effectively, emphasizing the unique advantages that differentiate the product from its rivals.

Disadvantages of USP

A marketing strategy centered on a unique selling proposition might restrict the variety of appeal possibilities. Attractions in a region that fail to meet USP criteria might be omitted from marketing initiatives. The diverse attractions of a nation provide strategic, tactical and operational benefits and marketing efforts focused on unique selling points might be neglecting the significance of this diversity. A diverse range of products can help a business reduce the risk of market downturns and is useful when a core product shows no potential for further growth. The USP focused marketing strategy works well for small areas with limited inherent appeal; larger countries with diverse attractions might discover it less appealing. The range of attractions and the rivalry among them in a tourist destination can impact the level of USP application in its advertising strategies for tourism.

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"ARTIFICIAL INTELLIGENCE: BENEFITS AND CHALLENGES IN EDUCATION"

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Introduction

Artificial intelligence (AI) is technology that enables computers and machines to simulate human learning, comprehension, problem solving, decision making, creativity and autonomy. Applications and devices equipped with AI can see and identify objects. They can understand and respond to human language. They can learn from new information and experience. They can make detailed recommendations to users and experts. They can act independently, replacing the need for human intelligence or intervention.

Artificial intelligence in education refers to the use of computer systems that can perform tasks typically requiring human intelligence to enhance learning experiences, streamline administrative processes, and support educators. AI technologies include machine learning, natural language processing and robotics, which can personalize learning by adapting content and pace to individual student needs. This personalized approach helps address diverse learning styles and paces, ensuring that each student receives the attention and resources they need to succeed.

In addition to personalized learning, AI can assist educators by automating administrative tasks. By reducing the time spent on these repetitive tasks, teachers can focus more on instruction and student engagement. AI-powered tools can also provide insights into student performance and progress, enabling early intervention for those who may be struggling

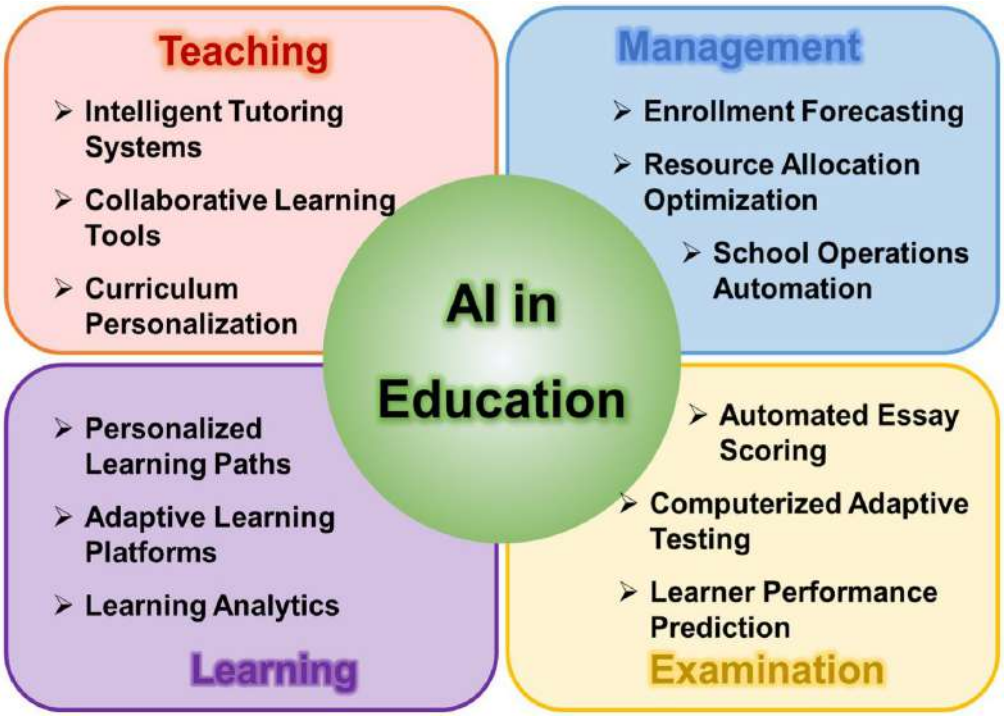
and recognizing those who excel. This data-driven approach allows for more informed decision-making and tailored support for students.

As artificial intelligence becomes more common in our daily lives, its effect on education calls for both enthusiasm and caution. Supporters believe that AI offers great opportunities for personalized learning, making administrative tasks easier and bringing new ways to teach. However, there are still worries about privacy, fairness and the possibility of replacing traditional teaching jobs.

A study by the Digital Education Council found that 86% of students admit to using AI in their studies. To further that, 24% use it daily and 54% use it weekly.

Some of the most common examples of AI in use today include:

- **ChatGPT:** Uses large language models (LLMs) to generate text in response to questions or comments posed to it.
- **Google Translate:** Uses deep learning algorithms to translate text from one language to another.
- **Netflix:** Uses machine learning algorithms to create personalized recommendation engines for users based on their previous viewing history.
- **Tesla:** Uses computer vision to power self-driving features on their cars.



Benefits of Using Artificial Intelligence in Education:

Personalized Learning

AI enables personalized learning by tailoring educational content to meet the unique needs of each student. Through adaptive learning technologies, artificial intelligence can analyze a student's strengths, weaknesses, learning pace and preferences. This data allows AI systems to provide customized lesson plans and resources, ensuring that students receive instruction that is best suited to their individual learning styles. As a result, students can progress at their own pace, which helps to improve understanding and retention of material.

Immersive Learning Experiences

Artificial intelligence has the potential to create immersive learning experiences that engage students in ways traditional methods cannot. Technologies such as virtual reality (VR) and augmented reality (AR) powered by AI can simulate real-world scenarios and complex concepts, making learning more interactive and enjoyable. For instance, students can explore historical sites, conduct virtual science experiments or practice language skills with AI-driven avatars, providing a hands-on learning experience that enhances comprehension and retention.

Improved Student Engagement and Motivation

AI creating immersive learning experiences also can result in boosting student engagement and motivation by making learning more interactive and personalized. Gamified learning platforms, powered by AI, incorporate game elements such as rewards, challenges and leaderboards to make learning fun and competitive. Additionally, artificial intelligence can provide instant feedback and support, helping students stay motivated and focused on their learning goals. By addressing individual needs and offering real-time assistance, AI helps maintain student interest and encourages active participation.

Cost-effective Learning

AI can make education more cost-effective by automating administrative tasks and providing scalable learning solutions. For example, artificial intelligence can handle routine tasks such as grading assignments, scheduling and managing student records, freeing up time for educators to focus on teaching. Additionally, AI-powered educational platforms can reach a large number of students with minimal additional cost, making high-quality education accessible to a broader audience. This scalability helps reduce the overall cost of education and ensures that more students can benefit from quality learning experiences.

Integrated Learning and Intelligent Tutoring System

AI-driven intelligent tutoring systems offer personalized guidance and support to students, mimicking one-on-one tutoring. These systems use data analytics to understand a student's learning progress and provide targeted feedback and recommendations. They can identify knowledge gaps, suggest relevant resources and adjust the difficulty level of tasks to match the student's abilities. By offering tailored support and continuous assessment, artificial intelligence helps students achieve their learning objectives more effectively.

Continuous Evaluation and Improvement in the Long Run

AI facilitates continuous evaluation and improvement by providing real-time insights into student learning performance and learning outcomes. Through data analytics, AI can track student progress, identify trends and highlight areas for improvement. Educators can use this information to refine teaching strategies, develop personalized interventions and ensure that learning objectives are being met. Continuous evaluation enables a proactive approach to education, where adjustments can be made promptly to enhance the learning experience and outcomes.

Raising Academic Standards and Educational Quality

The integration of AI in education has the potential to raise academic standards and improve the overall quality of education. Artificial intelligence can help ensure consistency and accuracy in grading, provide access to high-quality resources and support educators in delivering effective instruction. By leveraging AI technologies, educational institutions can offer a more rigorous and comprehensive curriculum that meets the evolving needs of students. AI can facilitate collaborative learning environments, where students and educators can share knowledge and resources, fostering a culture of continuous learning and improvement.

The advantages of AI in education are manifold, ranging from personalized and immersive learning experiences to cost-effective and high-quality education. As AI continues to evolve, its role in transforming education will become increasingly significant, offering new opportunities for students and educators alike.

Challenges of Artificial Intelligence in Education

As artificial intelligence continues to integrate into various sectors, its application in education is both celebrated and scrutinized. While AI holds significant potential to transform

learning experiences, it also presents several disadvantages that need careful consideration that must be addressed to ensure a balanced and effective learning environment.

Data Privacy Concerns

One of the primary disadvantages of AI in education is the issue of data privacy. AI systems often require vast amounts of personal data to function effectively, including students' academic records, behavioral data and even biometric information. This extensive data collection raises significant concerns about how this information is stored, used and protected. Inadequate safeguards can lead to data breaches, exposing sensitive student information to unauthorized parties and potentially resulting in identity theft or other forms of misuse. Ensuring robust data privacy measures and compliance with regulations is key to protecting students' information.

Dependence on Technology

Another major concern is the growing dependence on technology that AI in education fosters. As educational institutions increasingly rely on AI-driven tools for teaching, assessment and administrative tasks, there is a risk of becoming overly dependent on these technologies. This dependence can lead to significant disruptions in the event of technical failures or cyber-attacks. Furthermore, it may also diminish the development of critical thinking and problem-solving skills among students, as they may become accustomed to AI systems providing answers and solutions.

Lack of Human Touch/Dehumanized Learning Experience

The lack of human touch is a critical disadvantage of AI in education, leading to a dehumanized learning experience. Traditional education relies heavily on human interaction, with teachers providing not only academic instruction but also emotional support and mentorship. AI systems, while efficient, cannot replicate the empathy, understanding and personal connection that human educators offer. This absence of human elements can affect students' social and emotional development, as well as their overall engagement and motivation in the learning process.

Risk of Cheating

AI in education also raises the risk of cheating. Advanced AI tools can be exploited by students to find ways to bypass academic integrity measures. For instance, AI-powered plagiarism detection systems may themselves be outsmarted by sophisticated AI-generated content that mimics genuine student work. Additionally, AI-based tutoring systems and

automated assessments might be manipulated to provide undue assistance, undermining the fairness and integrity of academic evaluations. Schools and institutions must continuously adapt and update their AI tools to mitigate these risks.

Teacher Job Displacement

Lastly, the rise of AI in education brings the concern of teacher job displacement. As AI systems take on more roles traditionally filled by educators, there is a fear that teachers may become obsolete. Automated grading, AI-driven tutoring, and administrative tasks handled by AI could reduce the need for human teachers, leading to job losses and a devaluation of the teaching profession. While AI can certainly support and enhance educational practices, it is essential to balance its implementation to ensure that teachers remain integral to the educational process, providing the human touch that technology cannot replace.

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Abstract

Branding plays a vital role in establishing long-term competitiveness in any market. The agricultural sector often faces unique challenges when applying branding principles to its products. Branding has become a vital element in the agricultural industry, enhancing the marketability and perceived value of agricultural products. This article examines the role of branding in differentiating agricultural goods, fostering consumer trust and creating market competitiveness. By leveraging packaging, labelling and certifications branding helps producers move away from commodity-based competition and adds unique identities to their products. The study explores how branding allows farmers to command premium prices and align with consumer demands for transparency, sustainability and ethical sourcing.

Introduction

Agribusiness is a key contributor to the global economy, providing food, raw materials and economic value across both developed and developing nations. The industry spans a wide range of activities from primary production to processing, marketing and distribution. The increasing global demand for high-quality, traceable and sustainable food products has pushed the sector to innovate and evolve (Rizqan *et al*., 2022). Globalization and advancements in technology have opened new opportunities in international trade.

The tremendous competition in the global market makes it challenging for agricultural products from many countries to join global markets, despite the fact that these items have the

capacity to achieve it. Nations equipped with sophisticated agricultural technologies and efficient supply chains often dominate export markets, leaving developing countries at a disadvantage (Silaningsih *et al.,* 2024). Compliance with strict international standards for quality, safety and environmental sustainability adds another layer of complexity.

Evolving consumer behavior also plays a significant role. Modern consumers increasingly demand added value viz., organic production, environmentally friendly packaging or third-party certifications rather than basic quality (Ciptosari & Wadhi, 2023). To address these expectations, producers must adopt branding and differentiation strategies that clearly communicate the unique value of their products.

By emphasizing distinctive features like product origin, certification and innovation, differentiation allows agricultural products to stand out. Combined with strategic branding, this can create long-term value and a competitive edge in saturated markets (Sundayana *et al*., 2024).

Differentiation, Branding and Competitiveness: An Interdependent Relationship

In the global era, differentiation and branding combines to make product competitiveness. While differentiation adds specific attributes, viz., origin, quality or production methods. Branding ensures these features are effectively communicated to consumers. Without a clear brand identity, even high-quality products can remain unnoticed. A strong brand built on generic products may fail to retain consumer interest (Lifia & Rochmaniah, 2024).

Products that exhibit unique characteristics like sustainable practices or regional significance are better positioned for branding success. The standardized commodities without notable features present significant branding challenges (Nurisna & Rochmaniah, 2024). Strong differentiation helps build brand identity and elevate perceived value. Well-executed branding increases customer loyalty.

Consumers who identify with a product's story, taste or sustainability aspects are more likely to remain loyal and accept premium pricing (Bouchikhi, 2023). An example includes Colombian coffee and Belgian chocolate, which have gained International recognition through consistent branding and differentiation.

Developing and maintaining global branding strategies is resource-intensive and complex. It requires alignment with diverse consumer preferences and significant investment in marketing, design and logistics (Dinnie, 2022). A thoughtful integration of branding and differentiation can significantly improve international competitiveness (Martincevic, 2022).

Benefits of Branding

Companies use branding and the consumers' ability to identify brands to improve sales in four ways: to market new products, to protect market position, to broaden product offerings and to enter new product categories. The majority of small agribusiness owners make their branding debut by repackaging their existing products under the name of their farm, ranch, organization or business to promote brand recognition and to encourage the spread of experience attributes through word of mouth (Giddens *et al*., 2002).

Branded items are generally able to earn a higher price for the producer and can lead to brand loyalty, which leads to a strong customer base and the ability of the producer to better serve the needs of the market. Branding a product adds value by differentiating the product, making it stand out from the other items on the market and by conveying additional information about the attributes of the product beyond appearance. Branding also adds value to products simply because consumers generally believe that known branded products have better quality or more attributes than unbranded products. Another merit of branding is the sense of pride or community that can be experienced by the producer from successfully creating a brand identity (Giddens *et al.*, 2002).

Branding as a Driver of Global Competitiveness

Effective branding is essential for entering and thriving in international markets. The components are,

1. **Strong Differentiation and Added Value**: Products with identifiable qualities - cultural heritage, certification, or unique production methods have greater branding potential (Voldnes *et al*., 2023).
2. **Consistency across Channels:** A brand must maintain coherence in messaging, design, and product quality across markets. Consistency enhances trust and strengthens consumer relationships (Kauri *et al*., 2023).
3. **Utilizing Digital Tools and Storytelling:** Brands may reach a greater audience by utilizing digital marketing platforms. Storytelling-particularly stories about tradition or sustainability can increase the impact of branding (Yang *et al.*, 2022).
4. **Building Trust and Reputation:** Transparency, ethical practices and certification help build brand credibility. In global marketplace, consumers prioritize safety, sustainability, and ethics when making purchasing decisions (Octari *et al*., 2024).

Conclusion

The significance of branding and distinction in enhancing the international reputation of agriculture products is emphasized by this review. Differentiation adds unique value through quality, innovation and sustainability, while branding translates these attributes into tangible market benefits. By developing clear brand identities and aligning with global consumer expectations, agribusinesses can improve visibility, command premium prices and create more resilient export strategies. Producers and policymakers must invest in innovation, branding capabilities, digital engagement, and compliance with international standards. With the right combination of strategy and support, agricultural products can achieve broader global reach and contribute to economic growth in their regions of origin.

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ARTIFICIAL INTELLIGENCE (AI) IN AGRICULTURE AND ALLIED SECTORS

Article ID: AG-V05-I08-25

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Introduction

The growth of the global population, which is projected to reach 10 billion by 2050, is placing significant pressure on the agricultural sector to increase crop production and maximize yields. To address looming food shortages, two potential approaches have emerged: expanding land use and adopting large-scale farming, or embracing innovative practices and leveraging technological advancements to enhance productivity on existing farmland

Although there are several obstacles in achieving desired farming productivity like limited land holdings, labour shortages, climate change, environmental issues, and diminishing soil fertility etc., the modern agricultural landscape is evolving, branching out in various innovative directions. Farming has certainly come a long way since hand hoes or bullock-drawn machinery. Each season brings new technologies designed to improve efficiency and capitalize on the harvest. However, both individual farmers and global agribusinesses often miss out on the opportunities that artificial intelligence in agriculture can offer to their farming methods.

Artificial intelligence is based on the principle that human intelligence can be defined in a way that a machine can easily mimic it and execute tasks, from the simplest to those that are even more complex. The goals of artificial intelligence include learning, reasoning, and perception. Until recently, using the words AI and agriculture in the same sentence may have seemed like a strange combination. After all, agriculture has been the backbone of India which majorly contributing to economic development, while even the most primitive AI only emerged several decades ago. In recent years, the world has witnessed rapid advancements in agricultural technology, revolutionizing farming practices. These innovations are becoming increasingly

essential as global challenges such as climate change, population growth together with resource scarcity threaten the sustainability of our food system. Introducing AI solves many challenges and helps to diminish many disadvantages of traditional farming.

Applications of Artificial Intelligence in Agriculture

The industry is turning to Artificial Intelligence technologies to help yield healthier crops, control pests, monitor soil, and growing conditions, organize data for farmers, help with the workload, and improve a wide range of agriculture-related tasks in the entire food supply chain.

- **Use of weather forecasting:** Farmers can analyse weather conditions using weather forecasting, which helps them plan the type of crop that can be grown and when seeds should be sown, with the help of Artificial Intelligence.
- **Soil and crop health monitoring system:**
  - PEAT, a German digital start-up, has created Plantix, an AI-based application that can detect nutrient deficits in soil, as well as plant pests and diseases, and provide farmers advice on how to apply fertiliser to increase harvest quality. Image recognition technology is used in this app. Smartphones may be used by the farmer to photograph plants. Short movies on this application show soil restoration procedures, as well as recommendations and other solutions.
  - Trace Genomics, meanwhile, is a machine learning-based startup that assists farmers with soil analyses. Farmers may use such an app to track the quality of their soil and crops, resulting in healthier, more productive harvests.
- **Precision Farming and Predictive Analytics:** Agriculture AI applications have produced apps and tools that assist farmers in performing correct and regulated farming by offering suitable advise on water management, crop rotation, timely harvesting, kind of crop to be cultivated, optimum planting, insect assaults, and nutrition management.
  - AI-enabled technologies predict weather conditions, analyse crop sustainability, and evaluate farms for the presence of diseases or pests, as well as poor plant nutrition, using data such as temperature, precipitation, wind speed, and solar radiation in conjunction with machine learning algorithms and images captured by satellites and drones.
  - Farmers who don't have access to the internet may profit from AI right now using basic technologies like an SMS-enabled phone and the Sowing App. Meanwhile,

farmers with Wi-Fi connectivity may utilise AI programmes to acquire an AI-customized plan for their farms on a continuous basis.

- AI companies are developing robots that can easily perform multiple tasks in farming fields. This type of robot is trained to control weeds and harvest crops at a faster pace with higher volumes compared to humans. These types of robots are trained to check the quality of crops and detect weed with picking and packing of crops at the same time. These robots are also capable to fight with challenges faced by agricultural force labor.
- AI-enabled system to detect pests: AI systems use satellite images and compare them with historical data using AI algorithms and detect that if any insect has landed and which type of insect has landed like the locust, grasshopper, etc. And send alerts to farmers to their smartphones so that farmers can take required precautions and use required pest control thus AI helps farmers to fight against pests.

Challenges in use of AI for Agriculture:

1. **Large upfront costs**

   While AI solutions can be cost-effective in the medium-to-long-term, there's no escaping the fact that the initial investment can be very expensive.

2. **Reluctance to embrace new technologies and processes**

   Unfamiliarity often makes people hesitant to adopt new technologies creating difficulties farmers to fully embrace AI, even when it offers undeniable benefits. Resistance to innovation alongside some reluctance to take a chance on new processes hold back the farming methods development as well as the sector's profitability in general. Farmers need to understand that AI is only a more advanced version of simpler technologies for field data processing. To convince agricultural workers to embrace AI, the public and private sectors should provide motivation, resources, and training. Governments must also develop the regulations needed to assure workers that the technology is not a threat.

3. **Technological limitations**

   As AI is still developing, the technology will have constraints. Accurate models depend on diverse, high-quality data, which can be scarce in agriculture. For robots with sensors, limitations can make adapting to changing farming environments difficult. Overcoming these limitations requires ongoing research and analysis of data. Farmers

should also remain involved with decision-making rather than entirely handing control over to AI. Monitoring AI decisions manually is likely to be useful during the early stages of adoption.

4. **Privacy and security issues**

There is still a general lack of regulations relating to the use of AI across all industries. Particularly, implementing AI in precision agriculture and smart farming raises various legal questions. For example, security threats like cyberattacks and data leaks may cause farmers serious problems. It's even conceivable that AI-based farming systems could be targeted by hackers with the aim of disrupting food supplies.

Conclusion

Artificial intelligence in agriculture not only assists farmers in automating their agricultural operations, but also changes to precision cultivation for improved crop output and quality while using less resources.

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NANO IN YOUR PLATE: TRANSFORMING FOOD FROM WITHIN

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Abstract

Nanotechnology is transforming the global food industry by enabling precision in nutrient delivery, improving food safety, enhancing shelf life, and reducing post-harvest losses. This article explores the principles and practical applications of food nanotechnology, including nanoencapsulation, nano emulsions, smart packaging, and nano sensors. It highlights India's growing role in this sector through innovations led by institutions such as CFTRI, NIFTEM, and IITs, with support from agencies like DBT and DST. Special focus is given to cost-effective and culturally appropriate solutions, including the use of edible coatings and plant-based nanoparticles. The article also discusses emerging regulatory frameworks and safety concerns, underscoring the need for responsible innovation. Overall, food nanotechnology holds the promise of making food systems more functional, sustainable, and consumer-centric where even the tiniest particles can make the biggest impact.

Introduction

As the global population rises and dietary demands become increasingly diverse and health-driven, the food industry is under constant pressure to innovate. Among the most revolutionary scientific advancements influencing food today is nanotechnology a field that manipulates materials at the nanoscale (1–100 nm) to create functionalities previously unimaginable in food systems. Nanotechnology is not only reshaping electronics and medicine but is also making a significant impact in how we process, preserve, and consume food. By modifying the physical, chemical, and biological characteristics of food components, it enables

enhanced nutrient delivery, longer shelf life, better taste and texture, and smarter packaging solutions (Ravichandran, 2009).This integration of nanoscience into food science represents a leap toward solving real-world issues such as nutrient deficiencies, food spoilage, and inefficient delivery of bioactives. Importantly, it aligns with consumer demands for minimally processed, functional, and sustainable food options.

India, with its large-scale agricultural production and emerging food technology industry, has been a fertile ground for nanotechnology research and application in food. Emphasis on nutrition security, modernization of food processing, and functional foods has fostered public-private partnerships and inter-disciplinary research in leading institutions. Government organizations such as DBT, DST, and ICAR have funded several projects in nanoencapsulation, food-grade nano emulsions, and biodegradable nanocomposite packing. In addition, India's folkloric food science particularly in natural bioactives and plant-derived ingredients provides a distinctive edge in incorporating nanoscience within culturally acceptable food systems. From micronutrient-fortified staple foods via nano-carriers to shelf-life extension of perishables via nano-coatings, India is enthusiastically adopting innovation with affordability and scalability for small and medium enterprises (SMEs) in mind.

Applications of Nanotechnology in Food

Nanoencapsulation is amongst the most potential uses in the food sector. Bioactives such as curcumin, resveratrol, and omega-3 fatty acids tend to have issues like low solubility, poor stability, and low bioavailability. With the use of nanoencapsulation, these bioactives can be preserved from degradation and released in a controlled and targeted fashion, thus enhancing their functional activity (McClements & Rao, 2011).

In functional beverages, nanoemulsions are used to incorporate hydrophobic bioactives. These emulsions improve solubility, stability, and appearance of ingredients, allowing manufacturers to reduce the use of artificial additives while improving mouthfeel (Solans & Solé, 2012). Packaging has also seen a transformation with the introduction of nanocomposites such as silver, zinc oxide (ZnO), and titanium dioxide (TiO_2) nanoparticles. These materials inhibit microbial growth, delay spoilage, and provide barrier properties against moisture and gases, thus significantly extending the shelf life of food products (Emamifar et al., 2010).Additionally, nanosensors are being embedded into smart packaging systems. These sensors can detect gases like ethylene or indicators of microbial spoilage, allowing real-time

monitoring of food freshness and enhancing traceability and safety.Edible coatings and films made from nanoscale starch or chitosan are applied to fruits and vegetables. These coatings help reduce respiration rates, moisture loss, and microbial contamination, especially beneficial for extending the export potential of perishable produce.

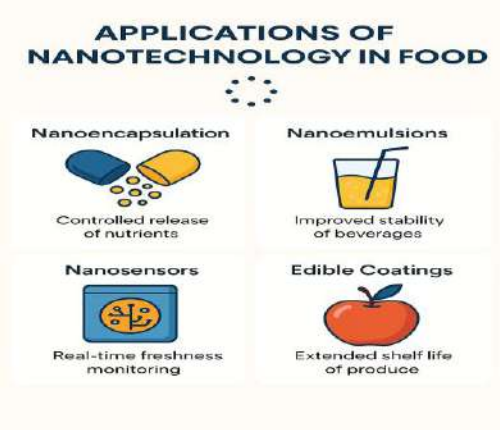

Figure 1: Key Applications of Nanotechnology in Food Systems

Key Benefits of Nanotechnology in Enhancing Food Quality and Safety

Table 1: Key Benefits of Nanotechnology in Food Systems

Application Area	Nanotechnology Role	Benefit Achieved	Reference
Nutrient Delivery	Nanoencapsulation	Improved bioavailability & stability	McClements & Rao (2011)
Beverages	Nanoemulsions	Enhanced solubility, mouthfeel, shelf life	Solans & Solé (2012)
Packaging	Nanocomposites (Ag, ZnO)	Antimicrobial effect, reduced spoilage	Emamifar et al. (2010)
Food Monitoring	Nanosensors	Real-time spoilage/pathogen detection	Kumar et al. (2020)
Coatings	Edible nano-films	Breathable barriers, reduce contamination	Emamifar et al. (2010)
Functional Foods	Nanoencapsulated phytochemicals	Controlled release, targeted delivery	McClements & Rao (2011)

India's Progress in Food Nanotechnology

Indian research centers like CFTRI, IITs, NIFTEM, and ICAR attached centers have achieved tremendous progress in food nanotechnology. These centers have been pioneers in the creation of novel, food-compatible nanomaterials and delivery systems appropriate to Indian nutritional requirements and climate. Some of the significant advances include the creation of Moringa seed protein nanoparticles for the encapsulation of hydrophobic bioactives like curcumin. These nanoparticles not only improve solubility and antioxidant properties but also provide a plant-derived, green solution over synthetic carriers (Sultana et al., 2020). In the same vein, potato starch-based nano emulsions are also being studied for the delivery of natural antioxidants such as quercetin, enhancing both their bio accessibility and storage stability (Ravichandran, 2009). Edible chitosan-based nano-coatings are another emerging innovation that actually extends the shelf life of fresh fruits and vegetables by preventing microbial growth and reducing moisture loss especially useful in India's tropical region (Emamifar et al., 2010).

These developments are being assisted by government-sponsored projects at the Department of Biotechnology (DBT) and Department of Science and Technology (DST), which focus on cost-effectiveness, safety, and scalability. Some research programs are designed especially to assist small-scale and rural food processors to ensure that high-end nanotechnological interventions can be realized in practical applications. In addition, the integration of India's ancient heritage in traditional medicine and diet (e.g., indigenous functional foods and Ayurveda) with contemporary nanotechnology is opening up the prospect of a distinctly Indian food innovation model. This intersection provides the twin benefits of scientificity and cultural fit, such that such nanofood solutions are effective and acceptable to the wider population.

Safety and Regulatory Concerns

Nanoparticles, being very small and of high surface reactivity, are capable of crossing biological membranes, being accumulated in tissues, and interacting at the genetic or cellular level. Such interactions can cause harmful effects like oxidative stress, DNA damage, and inflammatory reactions, and this is a concern for the safety of long-term exposure (Chaudhry et al., 2008). Regulatorially, national as well as international food safety agencies are proceeding cautiously. In India, Food Safety and Standards Authority of India (FSSAI) has started work to develop specific guidelines through its Scientific Panel on Functional Foods, Nutraceuticals, and

Novel Foods. These entail the suggestions for pre-market safety evaluation, labelling, and post-market monitoring of nano-enabled foods.

Worldwide, the FAO/WHO joint expert committee has set out a tiered risk assessment of nanomaterials in food, requiring comprehensive characterization, toxicological testing, and estimation of exposure. The European Food Safety Authority (EFSA) also requires case-by-case assessment of nanomaterials, focusing on particle size distribution, dissolution, and interaction with gut microflora. Labelling transparency, education of consumers, and uniform safety testing protocols are essential in facing risks and instilling confidence among the public in nano-enabled food systems.

Conclusion

Food nanotechnology is quickly moving from laboratory research to actual application. Its incorporation into food systems from nano encapsulated dietary supplements to smart packaging has already started to reshape the way we look at nutrition, safety, and sustainability. These nanoscale innovations allow for targeted delivery of nutrients, improve the functionality and shelf life of products, and provide real-time monitoring of food quality.While its revolutionary promise, however, calls for responsible innovation. Tight regulation, rigorous risk evaluation, and informed consumer awareness are needed to guarantee the safe and humane deployment of nanotechnology in food. Education and openness will be pivotal in building public trust and enhancing acceptance.

India, with its science capability, rich agri-food diversity, and growing demand for functional and fortified foods, is well-placed to take the lead in this sector. By developing cross-disciplinary collaborations, facilitating small-scale uptake, and bringing together indigenous food knowledge and advanced science, the country can be the champion of a sustainable nanotech revolution in food

"Sometimes, the smallest things make the biggest difference especially in what we eat."

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GENETIC PATTERNS OF BLOOD GROUP INHERITANCE: A COMMUNITY-BASED SURVEY FROM HYDERABAD– IMPLICATIONS FOR PUBLIC HEALTH AND DIAGNOSTICS

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Introduction

The discovery of the ABO blood grouping system by Karl Landsteiner in 1901 revolutionized medical science, ensuring safe blood transfusions and establishing blood groups as critical genetic markers. Building upon this foundation, a recent community-based initiative at Aparna Serenity, Hyderabad, Telangana, in collaboration with a private diagnostic centre, provided an opportunity to explore blood group inheritance patterns in a real-world setting. This study not only reinforces foundational genetic principles but also highlights their relevance to both diagnostic medicine and population health initiatives, fields central to modern Pathology and Family Medicine.

Background

The ABO and Rh blood group systems categorize human blood based on the presence or absence of antigens on red blood cells (RBCs). Blood group inheritance follows Mendelian genetic laws, with IA and IB alleles being co-dominant and IO recessive. The Rh factor further classifies blood as positive or negative. Understanding blood group distribution is essential not just for transfusion medicine but also for community health management, organ transplantation compatibility, and anticipating certain disease predispositions—skills vital for physicians across specialties.

Objective

This study aimed to analyze the blood group relationship between parents and their children within the Aparna Serenity community, utilizing real-world data obtained during a free

health camp. The goal was to validate genetic theories while simultaneously promoting blood group awareness, a step aligned with preventive healthcare initiatives.

Methodology

The study surveyed **150 residents**, collecting the following data through structured interviews:

- Participant's name and blood group
- Father's and mother's blood groups

The analysis focused on matching patterns between parental and child blood groups, evaluated across gender and age groups. This approach allowed for a comprehensive understanding of genetic transmission trends within a diverse urban community.

Findings and Discussion

1. Blood Group Distribution among Residents

Among participants, 'O-positive' (34%) was the most common blood type, followed by 'B-positive' (32%). The complete distribution included:

- A-positive: 31 residents
- B-positive: 49 residents
- AB-positive: 9 residents
- O-positive: 51 residents
- A-negative: 1 resident
- B-negative: 2 residents
- O-negative: 7 residents
- AB-negative: none

These figures align with established national trends in India, where Rh-positive blood groups are overwhelmingly dominant.

2. Gender-Wise Distribution

Gender-specific analysis showed:

- Males: Highest prevalence of 'O-positive' (40%).
- Females: Highest prevalence of 'B-positive' (36%).

Such data are valuable not only for academic purposes but also for establishing efficient community-based donor networks, a priority in both Family Medicine and Pathology practices.

3. Parent-Child Blood Group Matching

The inheritance analysis revealed:

- 88 residents (58.6%) matched their mother's blood group.
- 46 residents (30.6%) matched their father's blood group.
- 16 residents (10.6%) did not directly match either parent.

These findings validate classic Mendelian inheritance, while also underlining the occasional expression of recessive alleles, a concept crucial in genetic counseling and diagnostic workups.

4. Age Group and Gender-Specific Patterns

When stratified by age and gender:

- Younger individuals showed a higher maternal blood group matching.
- Males predominantly matched their mother's blood group (72%).
- Females more often matched their father's blood group (38%).

Such patterns suggest potential subtle gender-related trends that could be explored in future epidemiological studies.

5. Significance for Clinical Practice

Understanding blood group inheritance has practical clinical applications:

- **In Pathology**, accurate blood typing is critical for transfusion safety, hematologic evaluations, and organ transplantation.
- **In Family Medicine**, knowledge of blood group genetics supports prenatal counseling, prevention of hemolytic diseases of the newborn (HDN), and promotes personalized patient education initiatives.
- Community-level blood group registries, such as the one created through this initiative, can significantly improve response times during medical emergencies.

Explaining Non-Matching Cases

For participants whose blood groups did not match either parent, the outcomes were consistent with hidden recessive alleles and known genetic variability. Importantly, no data inconsistencies were observed, reflecting the reliability of the information collection process and reinforcing the importance of genetic literacy in primary care settings.

Community Health Implications

This study embodies the principles of proactive community healthcare by:

- Raising awareness about personal and family blood group status.
- Facilitating the foundation of an emergency donor registry.
- Highlighting the importance of basic genetic education in preventive health strategies.

These outcomes are particularly resonant with the broader goals of Family Medicine, which emphasizes community-oriented primary care, and with Pathology, which supports evidence-based diagnostics to inform patient care decisions.

Limitations

- The sample was limited to a single community.
- Parental blood group data were partially self-reported.
- Broader demographic factors such as ethnicity and inter-community marriages were not separately analyzed.

Future Directions

Expanding such studies across multiple residential communities could yield richer data and allow for:

- Analysis of blood group association with specific health risks.
- Establishment of decentralized blood donation networks.
- Advanced genetic counseling initiatives based on community-specific genetic patterns.

Conclusion

This community-driven blood group inheritance Community Health Study, conducted at Hyderabad, demonstrates the enduring relevance of classical genetics in modern clinical practice. It validates fundamental inheritance patterns, highlights practical public health applications, and underscores the importance of community participation in healthcare initiatives.

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EARLY CHICK CARE IN DESI FOWL: THE SECRET TO LOW MORTALITY AND HIGH RETURNS

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INTRODUCTION

Backyard poultry farming is a time-tested and sustainable livelihood option for millions of rural families across India, particularly in Tamil Nadu. It not only provides nutritious eggs and meat at the household level but also acts as a regular source of supplementary income, especially for women, landless laborers, and small farmers.

Among the various poultry types, desi fowls also known as native or indigenous breeds hold a special place. These birds are valued for their hardiness, excellent foraging ability, immunity to local diseases, better tolerance to climatic extremes, and superior meat and egg quality. However, despite these merits, the full potential of desi poultry is often undermined by high chick mortality, especially during the first 4–6 weeks of life. This early stage is extremely vulnerable, as chicks are not fully feathered, have immature immune systems, and are unable to regulate their body temperature. In rural settings where traditional methods dominate, lack of brooding facilities, poor nutrition, unhygienic conditions, predation, and absence of vaccination often result in chick mortality rates ranging from 30% to 50%, which significantly impacts flock size and profitability.

Each chick that dies early is a direct economic loss to the household—potential income, nutrition, and breeding potential are lost. This issue becomes more critical when poor families invest their limited resources in starting small-scale poultry units with high hopes. Fortunately, this challenge can be tackled with basic, low-cost, and farmer-friendly interventions in chick

management. Simple practices such as proper brooding, balanced feeding, timely vaccinations, clean housing, and ethnoveterinary remedies can drastically reduce mortality to below 10%, setting the stage for robust growth and better returns. This article presents a practical guide to effective early chick care in desi poultry, based on field experiences, success stories, and scientific recommendations. The aim is to empower rural poultry farmers with knowledge and tools that are easy to adopt, economically viable, and locally adaptable, leading to improved flock health, household nutrition, and income stability.

Desi Fowls – Built for the Backyard, But Not Without Care

Desi poultry breeds such as Aseel, Kadaknath, Gramapriya, and the commonly reared country chicken (Nattu Kozhi) are ideally suited for rural and semi-urban backyard conditions. These birds have been bred and raised for generations in local agro climatic environments, making them naturally resistant to many diseases and highly adaptable to harsh weather and limited feed resources. Their meat is tastier, has better texture, and commands a premium price in local markets. Eggs from native fowls are often preferred for their nutritional richness and are seen as a natural health supplement in many households.

Despite these natural advantages, desi chicks especially during the first four to six weeks of life are very delicate and vulnerable. Many poultry keepers assume that desi chicks need less care than improved or exotic breeds. This belief leads to a lack of attention in the critical early growth phase, resulting in high mortality and stunted development.

Let's understand why early-stage desi chicks are at high risk:

- Cold, wind, and rain exposure: Desi chicks, like all young poultry, cannot regulate their body temperature. In the absence of proper brooding facilities or warm shelter, they easily succumb to cold stress, especially during early mornings and rainy seasons.
- Predator attacks: In village settings, chicks are often left unattended in open spaces. They become easy prey for domestic cats, dogs, mongoose, kites, crows, and snakes. A few minutes of carelessness can wipe out an entire batch of young chicks.
- Nutritional gaps: Most rural farmers rely on broken rice, waste grains, or household scraps. These may fill the stomach but do not meet the high protein and energy needs of growing chicks. As a result, growth is poor, immunity is weak, and survival is compromised.

- Diseases: Chicks are prone to viral and bacterial infections. Newcastle Disease (Ranikhet) , and fowl pox are common threats. In the absence of timely vaccination and preventive care, outbreaks can spread quickly in flocks and wipe out dozens of birds within days.
- Unhygienic conditions: Chicks reared in damp, dark, and poorly ventilated places often suffer from respiratory problems and diarrheal diseases. Use of unclean feeders, water troughs, and wet litter only makes the environment worse.

Multiple field studies and farmer experiences across Tamil Nadu and other states clearly show that systematic early chick management even using low-cost methods can reduce mortality drastically. In projects conducted by KVK Kundrakudi , mortality rates came down from above 40 percent to less than 10 percent after introducing simple improvements like use of low-cost brooders, regular deworming, balanced feed, and basic health practices.

Thus, while desi fowls are hardy and naturally suited for backyard conditions, they are not self-sufficient during the early life stage. Proper warmth, protection, feeding, and vaccination are essential to unlock their full potential. The belief that "desi birds manage themselves" is a myth that needs to be corrected through awareness, demonstrations, and training.

Brooding – Warmth Is Life (0–4 Weeks)

Brooding is the most critical phase in chick rearing, especially during the first four weeks of life. It refers to the process of providing warmth, protection, and care to the chicks, helping them to adapt to their environment, develop their immune systems, and grow steadily. In natural conditions, a mother hen broods her chicks by sitting over them and offering warmth and safety. However, in semi-intensive or larger rural backyard systems, artificial brooding methods are preferred for better control and convenience.

Newly hatched chicks are not able to regulate their body temperature efficiently. Exposure to cold or sudden weather changes can lead to chilling, weakness, and even death. Therefore, creating a warm and comfortable environment during this stage is essential for survival and healthy development.

Temperature is the most important factor in brooding. The general rule is to start with a temperature of 95°F (35°C) during the first week and reduce it gradually by 5°F every subsequent week until the chicks are fully feathered by the fourth or fifth week. The temperature

must be monitored closely and adjusted depending on weather conditions. In colder months or during rainy days, extra heat sources may be needed for longer durations.

Apart from temperature, space and shelter also play a crucial role. Chicks must be provided with at least one square foot of floor space per chick. This helps prevent overcrowding, which can lead to piling, stress, and the spread of diseases. The floor should be covered with clean, dry bedding material such as rice husk, straw, wood shavings, or dry sand. Lighting is another important aspect of brooding. Continuous lighting during the first week ensures that the chicks are active, able to find feed and water, and remain warm. After the first week, the lighting duration can be gradually reduced, eventually following a natural day-night rhythm. Always ensure that feeders and waterers are placed within easy reach and cleaned regularly.

Proper ventilation must be maintained throughout the brooding period. Stuffy or air-tight brooder spaces lead to respiratory problems and poor growth. Fresh air should circulate without exposing the chicks to direct wind or cold drafts.

Thus, proper brooding is the foundation of healthy chick rearing. Whether one is raising ten chicks or a hundred, careful attention during these initial weeks makes all the difference between success and failure in desi poultry farming.

Feeding and Nutrition – Fuel for Growth

Nutrition is the backbone of any successful poultry enterprise. For desi chicks, especially in their first six weeks of life, proper feeding plays a vital role in ensuring strong growth, good immunity, and survival. Unlike adult birds that can forage and manage on kitchen scraps, young chicks require carefully balanced nutrition in both quantity and quality.A common mistake in backyard poultry farming is feeding chicks only with rice, grains, or leftovers from the kitchen. While these may fill the chicks' stomachs, they are nutritionally imbalanced and lack essential proteins, vitamins, and minerals needed for rapid growth and body development. Chicks fed this way often appear dull, have weak legs, poor feathering, and are more prone to diseases.

To ensure proper growth, chicks should be fed age-appropriate starter and grower feeds that are formulated with the right amount of protein, energy, and micronutrients.

Recommended feeding schedule:

- 0–2 weeks: Chick Starter Crumble with 22–23 percent protein. This fine-textured feed is easy to digest and supports early growth and bone development.

- 3–6 weeks: Grower Mash with 18–20 percent protein. It promotes muscle buildup, feathering, and internal organ development.

In rural areas where access to commercial feed may be limited or costly, farmers can use homemade feed mixtures made from local ingredients like ground maize, broken rice, soya meal, groundnut cake, fish meal, and mineral mixtures. Even partial supplementation with quality feed improves chick performance significantly.

Natural feed add-ons and indigenous practices:

To enhance the nutritional value of the diet, many farmers are successfully integrating natural, low-cost feed supplements that are locally available:

- Azolla: A floating aquatic fern rich in protein, calcium, and minerals. When dried and mixed with chick feed (10–15 percent), it improves growth and reduces feed cost.
- Moringa (drumstick) leaves: Packed with iron, vitamins, and antioxidants. Chopped fresh leaves or dried moringa powder can be added to the mash to boost immunity.
- Termites and ant eggs: Collected from anthills or termite mounds, these are traditional protein-rich feeds given to chicks in many tribal and farming communities.

Watering and supplementation:

Clean drinking water is just as important as feed. Chicks need round-the-clock access to fresh, cool water. Dirty or stagnant water quickly becomes a breeding ground for harmful bacteria, leading to diarrhoea or digestive problems.Clean water should be provided at least twice daily, and drinkers must be washed with mild disinfectant once every two days.During summer, adding electrolyte powder or glucose in the water helps prevent dehydration and heat stress.In the rainy season or during disease outbreaks, herbal decoctions made from tulsi leaves, ginger, pepper, and turmeric are given to improve digestion and respiratory health.

Farmers trained by KVK Kundrakudi reported that supplementing desi chick diets with azolla and moringa resulted in improved weight gain and reduced need for medicines.

Health and Vaccination – Prevention Is Profitable

Preventive health care is the most important investment a poultry farmer can make. Vaccination, hygiene, and close observation are critical in the early stages of chick growth. Even though desi birds are generally more disease-resistant than exotic breeds, young chicks are still highly vulnerable to viral and bacterial infections due to their immature immune systems.

Timely vaccination helps in building protective immunity against deadly diseases like Newcastle disease (Ranikhet) and Infectious Bursal Disease (Gumboro). Lack of vaccination is one of the top reasons for sudden chick deaths reported in village poultry units.It is important to administer vaccines during cooler parts of the day and ensure clean water during oral vaccination. Do not vaccinate stressed or sick chicks. Always follow proper cold chain maintenance if vaccines are brought from outside.Along with vaccination, maintaining biosecurity practices ensures the flock remains healthy. Even in small village units, basic hygiene and controlled movement around the chick-rearing area can make a big difference.

Key biosecurity tips include:

- Clean the brooder and litter daily
- Do not allow visitors or outsiders into the chick shelter
- Avoid mixing chicks with older birds
- Separate sick or weak chicks immediately for observation

Transition to Grower Phase – Smooth Shift Matters

- At around five to six weeks of age, chicks start developing full feathers and can slowly be shifted out of the brooder into the main backyard system. This transition is a delicate phase and must be managed carefully to prevent stress and setbacks in growth.
- Gradual outdoor introduction helps the chicks adapt to the environment while still receiving protection and supervision. Allow chicks to explore the outdoors during mid-morning and late afternoon hours when the temperature is moderate. Avoid exposing them to early morning dew, intense heat, or heavy rains.
- They should also be protected from predators like cats, dogs, mongoose, and crows. Foraging should be supervised in a fenced or netted area wherever possible.

- Feeding during this stage should include a mix of grower feed and locally available grains such as broken maize, ragi, kambu, and greens like agathi or amaranthus. This prepares the chicks for a foraging-based diet while still maintaining nutritional balance.
- Grower phase housing should be clean, raised above the ground to avoid dampness, and made with locally available materials like bamboo, bricks, and thatch. The shed must have proper ventilation, natural lighting, and clean drinking water. Night perches should be provided to allow the birds to roost safely off the ground.
- Deworming becomes important from this stage onward. It should be done once every 30 to 45 days using either herbal decoctions like neem-tulsi or veterinary-recommended dewormers based on veterinary advice.

In many villages across Tamil Nadu, women-led Self Help Groups (SHGs) are successfully managing chick rearing units as a part of income generation activities. KVKs and Veterinary University Training and Research Centers (TANUVAS) have trained hundreds of women in early chick management, vaccination, and marketing. These initiatives have improved family nutrition and added a stable stream of income to rural households.

Conclusion – Healthy Chicks, Healthy Livelihoods

Proper chick care in the first six weeks is the foundation of a profitable desi poultry unit. It is not an optional practice, but a necessary one. The success of the entire poultry enterprise depends on how well the chicks are managed during this early phase.

Warmth through brooding, balanced feeding, timely vaccination, clean shelter, and basic biosecurity can transform a handful of chicks into a healthy flock. With improved survival and growth, farmers can enjoy better income, household nutrition, and market returns.

As one farmer from Sivagangai district wisely said, **“A chick saved is an income earned.”**

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APPLICATIONS OF DRONES IN AGRICULTURE

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Abstract

Drones can be considered as an extremely valuable innovation to the farmers. Drones, while their applications extend beyond agriculture, in farming, these aerial devices are especially useful by providing accurate and timely data. Drones can check soil and fields to gather important information, spray fertilizers and pesticides precisely, reducing chemical waste, monitor how crops are growing, detect pests and diseases early and estimate crop yields accurately. Considering these significant benefits, farmers are gaining a lot from this technology. The paper deals with the application of drone technology in the field of agriculture.

Key words: Drones, UAVs, Agriculture, Digital technologies.

Introduction

India is primarily an agricultural country, but it faces challenges with low production and productivity. Many Indian farmers are not aware of modern farming technologies. Embracing the latest advancements can greatly enhance farm performance. Drones are becoming a popular tool in agriculture as part of sustainable farm management. They assist farmers, agronomists, and agricultural engineers in optimizing operations and utilizing powerful data analytics to better understand their crops.

Drones in Agriculture

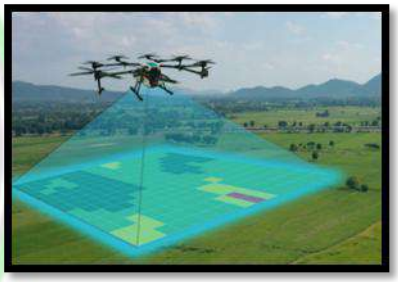
A drone is a flying machine that operates without a human pilot on board, also known as

an Unmanned Aerial Vehicle (UAV). Drones have become transformative tools in the agricultural sector. By combining advanced technology with traditional farming methods, they improve efficiency, productivity, and sustainability. Equipped with high-resolution cameras and sensors, drones provide farmers with real-time data on crop health, soil conditions, and field variability, allowing for precise decision-making. They are used in agriculture for various purposes, including soil and field analysis, crop monitoring, crop spraying, irrigation, and pest and disease assessment.

Agricultural Application of Drones:

Drones are making farming easier, more efficient, productive, and sustainable by providing real-time data and insights that improve crop yields, reduce costs, and minimize the environmental impact of agricultural operations. Their ability to quickly gather high-quality images and data has made them a popular tool in farming. Here are some ways drones are being used in agriculture:

Soil and Field Analysis:



Drones are being used in agriculture to analyze soil properties such as moisture levels, texture, compaction, and nutrient content. They help farmers understand the fertility of their land and whether it is suitable for agriculture.

Crop monitoring:

Drones equipped with cameras and sensors are becoming popular in agriculture for monitoring crops. They capture high-quality images and data about crop health, growth, and yield, providing farmers with valuable insights into their crops health status. This helps to identifying issues such as nutrient deficiencies, pest & disease infestations. Drone-based crop monitoring can be more efficient and cost-effective than traditional methods (Brajesh Kumar Lodhi *et al*. 2023).

Crop spraying:

Drones are designed to spray the fertilizers,

pesticides and herbicides. This way to minimize the excess application of chemicals and reduce the environmental pollution.

Irrigation:

By assessing moisture levels and identifying dry areas, drones enable precise irrigation management. This helps to reduce the moisture stress to the crops & minimize the crop failure.

Monitor crop growth:

Drones can provide accurate data at every stage of crops growth. If any problems arise during the crops growth, they can be identified before becoming serious. Multispectral images can show small differences between healthy and unhealthy crops that might be overlooked by the naked eye. For example, stressed crops will reflect less near-infrared light as compared to healthy crops. This difference cannot be detected by the human eye always. But drones can provide this information in the early stages (Gupta *et al*. 2022).

Yield estimation:

Drones are essential for estimating crop yields by monitoring growth with advanced imaging tools like multispectral and thermal cameras. These images help identify plant health, canopy cover, and moisture stress, which are important signs of yield potential. By analyzing this data, farmers can better predict their harvests and make timely decisions to increase productivity and profits.

Disaster risk Reduction:

Drones with advanced sensors quickly assess damage from natural disasters. They provide real-time data for making decisions and allocating resources. Their high-resolution aerial

images help evaluate the impact on agriculture, allowing for faster and more accurate damage assessments. Drones also monitor recovery progress, aiding in planning and resource allocation for land rehab, crop regrowth, and infrastructure reconstruction. (Satapathy *et al*. 2024).

Benefits of drones in the agriculture sector:

Drones are useful in farming like crop mapping, soil analysis, irrigation, and pest & disease management. Here are some of the benefits are given by utilizing drones in agriculture sector:

1. Enhanced efficiency

Drones help farmers quickly cover larger area, making easier to collect data and monitor their crops. This technology allows for early detection of problems, take quick and effective action.

2. Increased crop yields

Using drones to check crop health, it helps farmers find areas that need care. By fixing these issues, farmers can improve their crop yields and increase their profits.

3. Cost savings

Drones help save money by finding parts of the farm that need attention. This reduces the need for manual labour and lowers the use of pesticides and other chemicals.

4. High precision

Drones can take clear pictures and gather data, giving farmers a complete look at their crops. This helps them spot areas that need care and allows for focused and effective actions.

Conclusion

Drones are transforming agriculture by enabling precise crop monitoring, soil analysis and yield estimation, providing farmers with actionable insights to enhance productivity and sustainability. Equipped with multispectral and thermal imaging, they detect subtle plant stress, guide targeted irrigation and pesticide application and support accurate harvest forecasting. This data-driven approach not only boosts efficiency and profitability but also reduces chemical use and environmental impact. By automating key tasks and supplying real-time field intelligence, drones empower farmers to make informed decisions, respond swiftly to challenges and contribute to sustainable, resilient food systems.

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THE RISE OF ALTERNATIVE PROTEINS: BUSINESS MODELS FOR A SUSTAINABLE FOOD FUTURE

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Abstract

The world food system is confronted with serious challenges viz., population growth, environmental degradation and shifting consumer tastes. Alternatives to this are other proteins like plant and cell-based foods, which are coming forward as a revolutionary solution. This article discusses the different business models responsible for the development of the alternative protein market. It discusses their product development, market entry, consumer interaction and supply chain management strategies. Its points out the economic, environmental and ethical implications of this transition, citing the potential for these new models to alter the future of food production and consumption.

Introduction

Animal agriculture has been a mainstay in human diets for centuries, supplying dietary protein and playing an important role in global food supply. The environmental footprint of conventional livestock production, like greenhouse gas emissions, land use and water usage has created serious concerns. Growing awareness of animal welfare and health implications from conventional meat consumption is changing consumer demand. This synergy has established the platform for the dramatic growth of alternative proteins. Alternate proteins are generally termed as food alternatives replicating the taste, texture, and nutrition of conventional meat, dairy and eggs with non-animal materials. These primarily consist of:

- **Plant-based proteins:** Foods manufactured from ingredients as soya, peas, wheat and mushrooms which replicate animal products.
- **Cultivated (lab-grown) proteins:** Real animal meat, poultry, or seafood created by culturing animal cells without the need for raising and slaughtering animals.

The market for alternative proteins is growing rapidly, drawing in considerable investment and innovation. This article explores the various business models driving this industry forward, looking at how companies manage product development, scale production and capture market share in a fast-changing environment.

Business Models in the Alternative Protein Landscape

The alternative protein industry boasts a diverse variety of business models with their strengths and weaknesses. The models often overlap and evolve as the industry expands.

I. Plant-Based Protein Business Models

Plant-based businesses leverage existing farm infrastructure and focus on processing plant ingredients into recognizable food structures.

A. Ingredient Suppliers: These businesses produce and supply raw plant protein ingredients (e.g., pea protein isolate, soya protein concentrate) to food manufacturers.

- **Business Model:** B2B sales often with long-term contracts. They focus on efficiency, quality and cost-effectiveness of protein extraction and processing.
- **Key Success Factors:** Access to raw materials, advanced processing technology and strong research and development for functional ingredients.

  Examples: Ingredion, Roquette, Benson Hill.

B. Branded Product Manufacturers (B2C): These are most apparent and produce finished plant-based food products for consumers.

- **Business Model:** Produce and sell consumer-ready products (e.g., plant-based burgers, sausages, milk and yogurt). Distribution via retail (supermarkets, convenience stores) and food service (restaurants, cafes).
- **Key Success Factors:** Tastefulness and texture similar to traditional products, robust branding and marketing, efficient distribution channels, comparable pricing.

  Examples: Beyond Meat, Impossible Foods, Oatly, Miyoko's Kitchen.

C. Food Service - Directed Providers: Firms that specialize most heavily in restaurants, cafeterias and other food service operations.

- **Business Model:** B2B sales to large food service chains, typically with customized product development to meet individual menu requirements.
- **Key Success Factors:** Scalability of manufacture, consistent product quality and suitability to integrate into existing kitchen processes.
- **Examples:** Some branded product manufacturers also possess a large foodservice concentration (e.g., Impossible Foods' deals with fast-food restaurants).

D. Hybrid Models: Others hybridize elements of ingredient supply and branded product manufacturing or move into new product classes.

- **Business Model:** Diversification to get more value out of the supply chain.
- **Key Success Factors:** Vertical integration and solid research and development skills to innovate across product types.

II. Cultivated (Lab-Grown) Protein Business Models

Cultivated protein businesses work at the cutting edge of biotechnology, with a focus on cellular agriculture.

A. Cell Line Development & Bioreactor Technology: Cell line and bioreactor technology companies develop and optimize cell lines to be grown and build the bioreactor systems for mass-scale production.

- **Business Model:** Typically B2B, technology licensing or supply of specialized equipment and services to cultivated meat producers. Some might also create own cultivated meat products.
- **Key Success Factors:** Scientific expertise in cell biology and tissue engineering, effective and scalable bioreactor design, intellectual property protection.
- **Examples:** Future Meat Technologies (now a Believer Meats subsidiary), Mosa Meat, Upside Foods.

B. Final Cultivated Meat Companies (B2C/B2B): They develop the final product of cultivated meat for use by consumers or as an ingredient in other foodstuffs.

- **Business Model:** Selling directly to consumers (once regulatory challenges are overcome) or B2B sales to food companies to use in hybrid foods or as independent ingredients.

- **Critical Success Factors:** Price parity with traditional meat, regulatory approval, consumer acceptance, and scalable and efficient production processes.

  Examples: Upside Foods (chicken), Eat Just (chicken), Aleph Farms (beef).

C. Growth Media & Scaffolding Suppliers: Companies specializing in supplying the rich media and structural scaffolds necessary to support cell growth.

- **Business Model:** B2B sales to cultivated meat manufacturers.
- **Critical Success Factors:** Economically priced and food-grade growth media, novel scaffolding materials that simulate the structure of natural tissues.

  Examples: Biotechnology and biomaterials companies.

III. Cross-Cutting Business Model Considerations

In addition to certain product categories, there are a number of key business model considerations critical to success in the alternative protein industry:

A. Research & Development Focus:

- **Plant-Based:** Enhancing flavor, texture, nutritional content and ingredient performance, along with discovery of new plant sources.
- **Cultivated:** Scaling up, reducing growth media costs, creating sophisticated tissue architecture and gaining regulatory approval.

B. Supply Chain Management:

- **Plant-Based:** Providing access to affordable and sustainable plant-based ingredients, processing optimization and distribution.
- **Cultivated:** Providing a consistent supply of premium cell lines and growth media, bioreactor facility management and establishing cold chain logistics.

C. Regulatory Landscape:

- **Plant-Based:** Navigating labeling laws to provide accurate product claims.
- **Cultivated:** Obtaining approval for new foods, a lengthy and intricate process that includes thorough safety evaluations.

D. Consumer Acceptance & Education:

- Overcoming skepticism and educating the public regarding the benefits and character of alternative proteins. Marketing is crucial in influencing attitudes.

E. Sustainability and Ethical Positioning:

- Central to the value proposition is highlighting environmental advantages (less emissions, land, and water usage) and ethical aspects (animal welfare).

F. Investment and Funding

- The industry relies considerably on venture capital and strategic investments from big food corporations.

Table 1: Comparison of Business Model Aspects

Feature	Plant-Based Protein Business Models	Cultivated Protein Business Models
Primary Inputs	Crops (soy, pea, wheat, fungi), water, energy	Animal cells, growth media, water, energy
Production Scale	Often large-scale processing, can leverage existing food infrastructure	Currently small-scale, significant R&D needed for industrial scale
Technology Focus	Food science, ingredient functionality, processing techniques	Cell biology, tissue engineering, bioreactor design
Regulatory Path	Generally less complex, focus on labeling and food safety	Highly complex, novel food approval, safety assessments
Cost Structure	Ingredient costs, processing, marketing	R&D, growth media, bioreactor capital expenditure, energy
Market Readiness	Already established in retail and foodservice	Early stages, limited commercial availability
Consumer Perception	Growing acceptance, some "ultra-processed" concerns	"Lab-grown" perception, need for education and transparency
Environmental Impact	Significantly lower than conventional meat	Potentially much lower than conventional meat (long-term)

Challenges and Opportunities

Challenges	Opportunities
Taste and Texture Parity	Solving Food Security

Price Parity	Reducing Environmental Impact
Scaling Production	Benefits to Public Health
Regulatory Clarity	Economic Development
Consumer Education & Supply Chain Resilience	Technological Innovation

Conclusion

The alternative protein market is a watershed moment in the development of our food system. Plant-based and cell-cultivated food business models are changing quickly through consumer traction, environmental imperatives, and technological innovation. Though taste, cost, scalability and regulatory hurdles still exist, the direction of the industry is toward a future that includes more diverse, sustainable, and morally produced proteins in the diet worldwide. The future success of these business models will rely on their capacity to deliver tasty, affordable, and available foods that appeal to consumers, ultimately leading to a more sustainable and resilient food future.

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NATURE'S SILENT SOLDIERS: UNLEASHING PARASITOIDS AND PREDATORS IN SMART IPM

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Abstract

The growing reliance on chemical pesticides has triggered ecological imbalance, pest resistance, and environmental hazards, urging the adoption of sustainable pest management strategies. This article explores the practical role of biological control agents—specifically Trichogramma (egg parasitoid), Chrysoperla (predator of soft-bodied insects), and coccinellids (ladybird beetles)—in Integrated Pest Management (IPM). Field evaluations were conducted to assess their efficacy against major crop pests under diverse agro-climatic conditions. Results revealed a significant reduction in pest populations and crop damage, with improved natural enemy survival and minimal non-target effects. The integration of these biocontrol agents reduced the need for chemical inputs by over 50%, promoting environmental safety and sustainable yield.

Keywords

Biocontrol, Parasitoids, Predators, Trichogramma, Chrysoperla, Coccinellids, Sustainable Agriculture, IPM, Natural Enemies, Pest Suppression, Augmentative Release, Ecological Balance, Crop Protection, Chemical Reduction, Biodiversity, Field Trials, Predator-Prey Dynamics, Conservation, Agro-ecosystem, Pest Management.

Introduction

Modern agriculture faces a dual challenge: ensuring high productivity while minimizing ecological and health risks posed by indiscriminate pesticide use. Integrated Pest Management

(IPM) offers a holistic approach, and among its most sustainable components is biological control using natural enemies such as parasitoids and predators. *Trichogramma spp*. Parasitize pest eggs, *Chrysoperla carnea* targets soft-bodied pests like aphids and whiteflies, while coccinellids feed on a wide range of pests, especially aphids and mealybugs. The objective of this investigation was to evaluate the effectiveness of these key biocontrol agents in real-time cropping systems. Prior research highlights their potential, but practical adoption remains limited due to various field-level challenges.

Table 1: Common Biocontrol Agents and Their Target Pests

S. No	Biocontrol Agent	Type	Target Pests	Crops Commonly Used In
1	*Trichogramma chilonis*	Egg Parasitoid	Cotton bollworms, Rice stem borer	Cotton, Rice, Sugarcane
2	*Chrysoperla carnea*	Predator	Aphids, Thrips, Whiteflies	Vegetables, Fruits, Ornamentals
3	*Coccinella septempunctata*	Predator	Aphids, Mealybugs	Pulses, Oilseeds, Vegetables
4	*Bracon hebetor*	Larval Parasitoid	*Helicoverpa*, *Spodoptera* spp.	Maize, Pulses, Groundnut
5	*Cryptolaemus montrouzieri*	Predator	Mealybugs	Grapes, Citrus, Ornamentals
6	*Aphidius colemani*	Aphid Parasitoid	Green peach aphid, Cotton aphid	Greenhouse crops, Vegetables
7	*Encarsia formosa*	Nymphal Parasitoid	Whiteflies (*Bemisia tabaci*)	Tomato, Brinjal, Capsicum (Polyhouse)
8	*Telenomus remus*	Egg Parasitoid	*Spodoptera litura*, Armyworm	Cotton, Maize, Soybean
9	*Orius insidiosus*	Predator	Thrips, Aphids, Mites	Flowers, Vegetables
10	*Nesidiocoris tenuis* (Green mirid bug)	Predator	Whiteflies, Moths	Tomato, Chilli

Source :- https://napis.pestmonitoring.com

Role of Parasitoids: Trichogramma as a Key Player

Parasitoids are insects whose immature stages develop inside or on a single host insect, ultimately killing it. Among them, *Trichogramma species* are the most widely utilized egg parasitoids in agricultural IPM programs. They lay their eggs inside the eggs of target pests, preventing larval emergence and thus disrupting the pest life cycle at an early stage.*Trichogramma chilonis, T. japonicum, and T. brassicae* are commonly released against lepidopteran pests like *Helicoverpa armigera, Chilo partellus, and Scirpophaga incertulas*. These parasitoids are mass-produced on surrogate hosts like *Corcyra cephalonica* eggs and are distributed using biodegradable cards.

Picture of *Trichogramma sp* Source : https://www.buglogical.com

Mass Production procedure:

In India eggs of *Corcyra cephalonica* (rice moth), a stored grain pest has been used for mass multiplication of Trichogramma species.

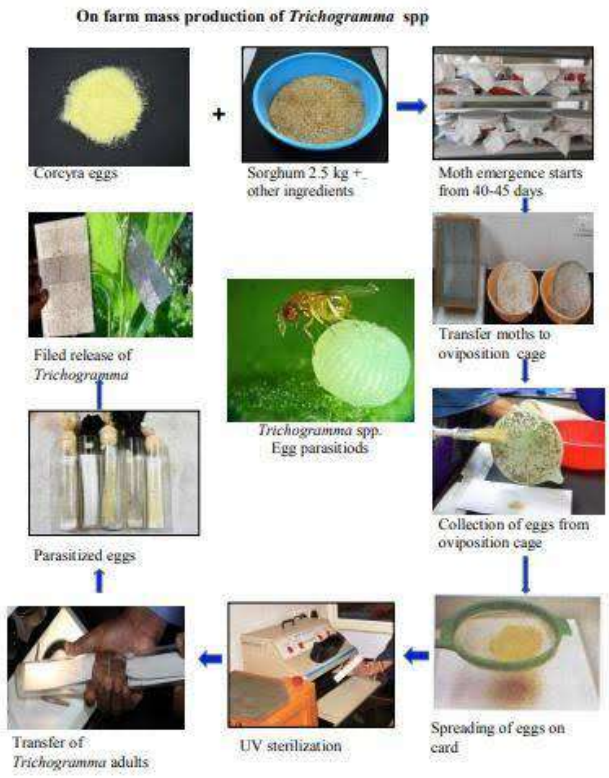
Mass Production Corcyra eggs

1. Corcyra feed is prepared using Cumbu grains. The requisite quantum of Cumbu is milled to make 3-4 pieces of each grain. Milled grains are heat sterilized in a hot air oven at 100°C for 30 minutes and the grains are sprayed with 0.1% formalin. Then grains are air dried.
2. In each plastic rearing tray, 2.5 kg of prepared Cumbu grains are filled and added with 100 g groundnut powder, 5 g yeast, 5 g sulphur, 0.05 % Streptomycin sulphate to enhance egg laying capacity of the adult moths and for enriching the diet.
3. Each tray is charged with 0.5cc eggs (1cc = 20,000 eggs) of mother culture and cover with cloth.
4. Corcyra (rice moth) develops in the tray.
5. The duration of various life stages are Egg: 3 days, Larva: 35 days, Pupa: 7 days.

6. After about 40 days of charging, moths start emerging and the emergence continues for two months.
7. Adults are collected by using vacuum collector, transfer to matting cage and provide adult food.
8. The loose eggs laid by Corcyra (rice moth) are collected and the scales are cleaned with sieve or egg separator.
9. Use 25% eggs for recycling the insect culture and 75% for Trichogramma production.

Mass Production Trichogramma

1. Thus, the cleaned eggs are spread on the gummed commercial cards (15 cm x 10 cm) with the help of a sieve.
2. Then these commercial cards spreaded with Corcyra eggs are exposed to UV rays of 15 watt UV tube for 45 minutes to prevent hatching. While UV exposure, egg card should be kept about 12-15 cm away from tube. This is called UV sterilization.



Mass Production Of *Trichogramma spp*

Source :- https://images.app.goo.gl

3. After sterilization the egg cards are placed in plastic bottle or polythene cover and are introduced with nucleus culture of Trichogramma. The ratio of host egg and parasite adult should be maintained at 1:5 (about 1 cc of nucleus card with honey and vitamin E for about 5 cc of commercial card).
4. Adult emerges out from the nucleus card parasitizes the eggs of commercial card.
5. After 4 days, observe blackening of commercial egg cards.
6. These cards can be stored in refrigerator at 5-100C for 10-15 days.

Predatory Power of *Chrysoperla carnea*

Chrysoperla carnea, commonly known as the green lacewing, is an efficient predator of aphids, thrips, whiteflies, and other soft-bodied pests. Its larval stage is particularly voracious, often referred to as "aphid lion." Lacewings are highly adaptable, and they do not harm beneficial insects. Commercial production of Chrysoperla is expanding, and augmentative releases in vegetable and horticultural crops have shown excellent pest suppression with minimal input costs.

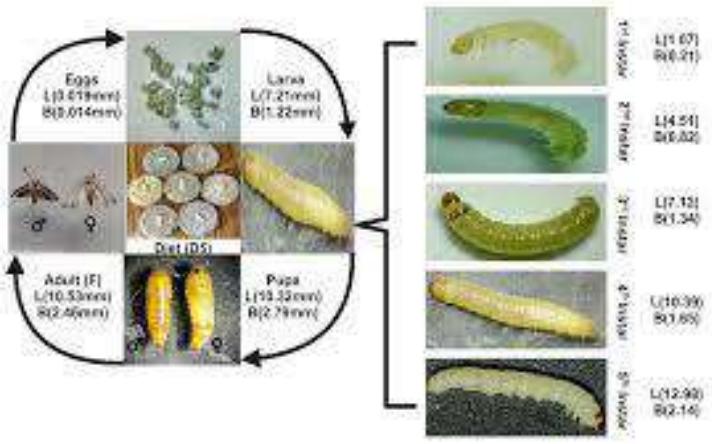
Picture of *Chrysoperla carnea* Source: https://stock.adobe.com

Mass Production Chrysoperla

1. Chrysoperla are mass multiplied in laboratory at 27 ± 10C and 70% RH on the eggs of *Corcyra cephalonica*, a laboratory host.
2. The adults of Chrysoperla are released in to glass troughs (30 cm x 12 cm) which is wrapped inside with brown sheet and secured by rubber band (@ 50 adults/trough) or Rectangular oviposition cage (2' x1' x1') with sliding top and lined with black cloth to receive the eggs (@ 100 adults/cage).
3. An artificial protein rich diet is provided for adults. This diet consists of one part of powdered yeast, fructose, honey, Proteinex R and water in the ratio 1:1:1:1.
4. The adults in the oviposition cage or trough are also provided with castor pollen and 50% honey and drinking water in cotton swab.

5. Matting takes place in two days and eggs are laid after four days on the brown sheet in the through or on the black cloth of the oviposition cage.
6. Brown paper sheets or black clothed sliding tops with Chrysoperla eggs are taken out daily and change with new one.
7. After 24 hours of hardening the collected eggs are gently destalked using brush. (As such, the sheets can be stored at 10oC in B.O.D. incubator or refrigerator for about 21 days. When the eggs are required for culturing or for field release the egg sheets are kept at room temperature for a day and used.)
8. Then two day old, destalked Chrysoperla eggs @ 120 eggs are mixed with 0.75 ml of Corcyra eggs (the embryo of Corcyra eggs are inactivated by keeping them at 2 feet distance from 15 watt ultraviolet tube light for 45 minutes) and transferred to a plastic container (27 x 18 x 6 cm). On hatching, the Chrysoperla larvae feed on Corcyra eggs. It is assumed that for rearing 100 larvae 1cc of Corcyra eggs are required.

Mass Production of *Corcyra cephalonica*



Source : https://link.springer.com

9. After 3rd day the Chrysoperla larvae are transferred to 2.5 cm cubical cells of plastic louvers @ one per cell.
10. Corcyra eggs are provided in all the cells of each louver by sprinkling through the modified salt shaker. Feeding is provided in two doses. First feeding of 1.5 ml Corcyra eggs for 100 larvae and second feeding of 2 ml for 100 larvae with a gap of 3-4 days is done. Total quantity of Corcyra eggs required for rearing 100 Chrysoperla larvae are 4.25 ml.

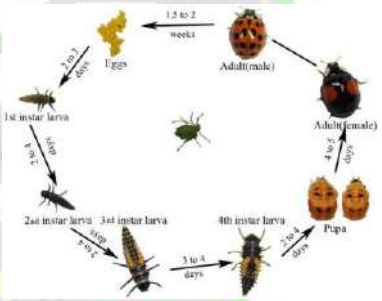
11. The louvers are provided brown paper sheet and after transfer of larvae covered with acrylic sheet and clamped. Brown paper is used for facilitating pupation and clear visibility of eggs. The louvers are stacked in racks.
12. Cocoons are collected after 24 hours of formation (when they get hardened) by removing brown paper.
13. The cocoons are placed in adult oviposition cages for emergence.

Importance of Coccinellid Beetles in Agroecosystems

Ladybird beetles (Coccinellids), especially *Coccinella septempunctata*, are well-known predators of aphids, mealybugs, and mites. Their robust feeding capacity and adaptability make them valuable agents in field and greenhouse conditions. They also serve as indicators of ecological health. Conservation of native coccinellid populations by avoiding broad-spectrum insecticides can significantly enhance natural pest control in various cropping systems.

Picture of *Coccinella septempunctata*

Life Cycle Of Coccinellids



Source: https://influentialpoints.com

Integration and Field-Level Challenges

While the potential of these biocontrol agents is well-documented, field-level adoption faces hurdles such as farmer unawareness, lack of timely availability, and the need for synchronization with pest population dynamics. Climatic conditions, such as temperature and humidity, influence the performance of these agents. To overcome these barriers, there is a pressing need for farmer training programs, subsidies for biocontrol products, and collaboration between research institutions and extension services. Successful integration of biocontrol into IPM requires a systems-based approach that balances pest suppression, ecological safety, and economic viability.

Table 2: Comparative Advantages of Biocontrol Agents in IPM

S. No	Agent	Method of Action	Key Advantages	Limitations
1	*Trichogramma* spp.	Parasitism (egg stage)	Prevents pest emergence, cost-effective, early control	Sensitive to weather, requires timely release
2	*Chrysoperla carnea*	Predation (larval stage)	Broad pest range, easy mass production	May migrate if prey density is low
3	*Coccinella septempunctata*	Predation (nymph & adult)	Self-sustaining, effective against aphids/mealybugs	Less effective in monocultures
4	*Bracon hebetor*	Parasitism (larval stage)	Targets lepidopteran caterpillars	Needs host larvae presence
5	*Cryptolaemus montrouzieri*	Predation (mealybugs)	Excellent in orchards and polyhouses	Sensitive to broad-spectrum insecticides

Source :- https://nbair.res.in

Conclusion

Biological control, particularly through the use of effective natural enemies like Trichogramma, Chrysoperla, and coccinellids, presents a practical and sustainable alternative to chemical pesticides in IPM systems. The study confirms that these agents significantly reduce pest populations, enhance ecological balance, and improve crop health without harming non-target organisms. Despite some challenges-such as environmental dependency, predator-prey timing, and lack of awareness among farmers -the advantages in terms of reduced pesticide usage, cost-effectiveness, and long-term sustainability are evident. For wider adoption, increased farmer training, consistent quality production of biocontrol agents, and supportive policy frameworks are essential. Integrating these biological solutions into mainstream agriculture is no longer optional, but imperative for achieving sustainable, eco-friendly pest management in India and beyond.

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ARTICULTURE: WHERE ART MEETS AGRICULTURE

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Introduction

The term "Articulture" is a conceptual blend of "Art" and "Agriculture," signaling a movement where creativity merges with cultivation. While agriculture represents the ancient practice of growing and nurturing life from the soil, art reflects human emotion, expression, and aesthetics. When these two domains intersect, they form a vibrant, living canvas — Articulture, where land becomes gallery, farming becomes performance, and nature becomes medium. Articulture is not merely decorative landscaping or eco-art. It is a philosophy of living, encouraging sustainable interaction with the environment while embedding beauty and meaning into utilitarian spaces like farms, gardens, and community landscapes. It stands as a response to the urban alienation from nature and an artistic critique of industrial agriculture.

1. Historical Background: Art and Agriculture through the Ages

Though the term "Articulture" is contemporary, the interlinking of art and cultivation is ancient. Indigenous cultures worldwide have long practiced ceremonial planting, sacred landscapes, and symbolic harvest rituals that represent more than just food production.

Ancient Traditions:

- Mesopotamian gardens were created as symmetrical, ornamental spaces blending function and form.
- Japanese Zen gardens illustrate spiritual harmony, using rocks, sand, and plants as symbolic expressions.
- In India, temples often featured courtyard gardens that reflected cosmic designs and religious narratives.

- In Europe, the Renaissance brought the rise of aesthetic farming, especially in palace grounds like Versailles where agriculture became an extension of royal art.

These historical instances reveal that agriculturists have long embraced artistic form — even before the formal idea of "Articulture" emerged.

2. Defining Articulture Today

In the modern context, Articulture can be defined as: The integration of artistic expression into agricultural, horticultural, or ecological settings, creating experiences that are functional, sustainable, and visually or emotionally engaging.

This can include:

- Sculptural elements in farms.
- Edible landscaping in urban spaces.
- Vertical gardens with artistic patterns.
- Artistic greenhouses or community farms with curated design.

Subcategories:

1. Agri-sculpture – Large-scale installations made from natural or farm-related materials.
2. Living art – Art made with growing plants, such as topiaries or moss graffiti.
3. Land art – Earthworks and environmental installations that reshape natural landscapes.
4. Permaculture aesthetics – Sustainable design blended with symmetry, pattern, and beauty.

3. The Principles of Articulture

Articulture functions on a set of core principles that distinguish it from conventional agriculture or public art:

1. Ecological Integrity

- Plants used are often native, pollinator-friendly, and water-efficient.
- Zero-waste materials and eco-sensitive methods are prioritized.

2. Community Engagement

- Community gardens become co-created artworks.
- Children, artists, and farmers collaborate in designing spaces.

3. Aesthetic Value

- Shapes, symmetry, patterns, and color theory play major roles in layout and planting schemes.

- Artistic curation enhances emotional connection to green spaces.

4. Functionality

- Despite artistic design, the spaces often serve as active gardens or food producers.

5. Storytelling and Symbolism

- Many Articulture projects embed narratives — cultural heritage, social themes, or environmental messages.

4. Real-World Examples of Articulture

A. Storm King Art Center, USA

A vast sculpture park where art and landscape blend into rolling hills, forests, and fields.

B. The Eden Project, UK

Biodomes designed like futuristic greenhouses house art, science, and sustainable agriculture in one massive installation.

C. Vertical Forests, Italy

Architect Stefano Boeri's towers in Milan integrate more than 20,000 plants into residential skyscrapers — turning urban architecture into living artwork.

D. Agro-ecological Community Gardens in Cuba

During the food crisis, Cuba's community gardens became both survival spaces and expressions of resilience and pride.

E. Terrace Gardens of Peru

Ancient Incan terraces blend agricultural utility with astonishing geometrical beauty — an early example of indigenous Articulture.

5. The Aesthetic Language of Plants

Every plant carries visual, emotional, and symbolic language. In Articulture, selecting flora is like choosing a color palette:

- Lavender and rosemary suggest calm and healing.
- Sunflowers evoke joy and openness.
- Creepers and vines express flow, growth, and movement.
- Succulents and cacti represent resilience and minimalist beauty.

The choice of plant species, their spacing, and even flowering cycles are choreographed to express seasons, mood, and message.

6. Articulture in Urban Landscapes

With cities expanding and natural spaces shrinking, Articulture offers a healing bridge between urban infrastructure and nature.

Applications include:

- Rooftop gardens with geometric layouts.
- Community vegetable walls with murals.
- School yards with art-integrated food patches.
- Road medians with sculptural flora arrangements.

These not only beautify the city but also clean air, reduce heat, and provide food — an aesthetic and ecological intervention.

7. Art as Activism in Agriculture

Artists globally have used Articulture as a medium of protest, awareness, and dialogue:

- Seed art installations to protest GMO crops.
- Performance farming, where artists cultivate land as part of an artistic act.
- Interactive food gardens that invite public participation in sustainability.

These works create powerful emotional impact, promoting climate literacy, soil health awareness, and biodiversity preservation.

8. Educational and Therapeutic Dimensions

Articulture is increasingly adopted in:

- Rehabilitation centers for mental health therapy.
- Schools as part of STEAM (Science, Technology, Engineering, Art, Math) education.
- Hospitals to create healing green environments.
- Refugee camps where displaced communities reclaim agency through soil and expression.

Benefits include:

- Reduced stress and anxiety, Improved focus and emotional resilience.
- Strengthened environmental consciousness in children.

9. Technological Innovations in Articulture

Even technology has a place in Articulture:

- Digital irrigation and hydroponics merged with aesthetic garden structures.
- 3D-printed planter systems designed with symmetry.
- AR experiences that allow users to explore plant stories via smartphones.

Articulture thus becomes a cross-disciplinary arena, where science, art, and culture coalesce.

10. Challenges and Ethical Questions

While beautiful, Articulture is not free from criticism and caution.

- Can artistic modifications compromise ecological balance?
- Is it ethical to "design" nature, or should we let it be?
- Does Articulture risk becoming elitist or gentrified?
- How do we ensure inclusivity in designing public spaces?

These questions push practitioners toward more inclusive, sustainable, and community-led forms of Articulture

11. Articulture in the Indian Context

India, with its rich agricultural traditions and spiritual art forms, is a fertile ground for Articulture:

- Temple gardens, sacred groves, and the Tulsi Vrindavan are heritage forms.
- Terracotta art in farming villages, kolams in fields, and flower rangolis reflect aesthetic agriculture.
- Modern movements such as permaculture farms, eco-retreats, and cultural gardens are reshaping the scene.

The Govardhan Ecovillage, Auroville, and several agro-tourism spots are blending spiritual, ecological, and artistic life — perfect embodiments of Articulture.

12. The Future of Articulture

Articulture is more than a trend — it's a transformative lens through which we can reimagine:

- Food systems that are nourishing and beautiful
- Urban life that's more in touch with the earth
- Education that integrates creativity and sustainability
- Economies that value biodiversity and artistic heritage

As climate change and urban loneliness grow, Articulture may become a core element of sustainable future living — returning us to nature, not just functionally, but with awe and affection.

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USE OF CHEMICALS IN POST-HARVEST LIFE OF TOMATO, MELON AND SQUASH, CUCUMBER, COLE CROPS, BULB AND TUBER CROPS THEIR APPLICATION METHODS

Article ID: AG-VO5-I08-33

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Introduction

Fresh vegetables are living, perishable commodities that continue their metabolic activities even after harvest. Processes such as respiration, transpiration, and enzymatic changes lead to gradual deterioration in appearance, texture, flavours, and nutritional quality. Additionally, microbial attack accelerates spoilage, resulting in significant postharvest losses, especially in regions with inadequate storage and transportation infrastructure.

To address these challenges, **postharvest chemicals** are applied as part of integrated handling practices to slow down deterioration, maintain quality, and extend the shelf life of vegetables. These chemicals work by inhibiting microbial growth, reducing physiological activity, delaying ripening, and minimizing moisture loss. They can be used in various forms, including sprays, dips, fumigants, wax coatings, and modified atmosphere packaging treatments.

Common categories of postharvest chemicals for vegetables include; **Antimicrobial agents** (e.g., chlorine, sodium hypochlorite, peracetic acid) to control surface microorganisms. **Growth regulators** (e.g., gibberellic acid, 1-methylcyclopropene) to delay senescence and ripening. **Anti-sprouting agents** (e.g., maleic hydrazide, CIPC) for root and tuber crops. **Fungicides** (e.g., thiabendazole, imazalil) to reduce fungal infections during storage and transport. **Surface coatings and waxes** to reduce water loss and delay shrivelling.

Tomato

- **Chlorothalonil and anilazine** have been extensively used to protect plants and the fruits against ***Botrytis*** **infection**.

- **Chlorothalonil** is also effective against ***Alternaria alternata*.**
- **Benomyl and thiophanate methyl** have provided control of ***Botrytis.***
- **Iprodion and vinclozolin** have been used experimentally as alternatives to the benzimidazole for *Botrytis* control.

Melons and squash

- **Benomyl** was very active against *Fusarium*, **imazalil** against *Fusarium* and *Alternaria*, **guazatine** against *Geotrichum* and *Alternaria*.
- **Fenaminosulf** was effective against *Rhizopus oryzae*.
- **A mixture of benomyl (250 mg/l) and guazatine (500 mg/I)** controlled all diseases (*Fusarium*, *Geotrichum*, *Alternaria*, *Cladosporium*, and *Rhizopus*) on naturally inoculated cantaloups.
- A wax formulation containing **0.2% dicloran** controlled ***Sclerotinia sclerotiorum and Botrytis spp.*** on zucchini squash stored at 8°C.
- **Fumigation of squash with a thiabendazole** smoke was effective against *Sclerotinia*.

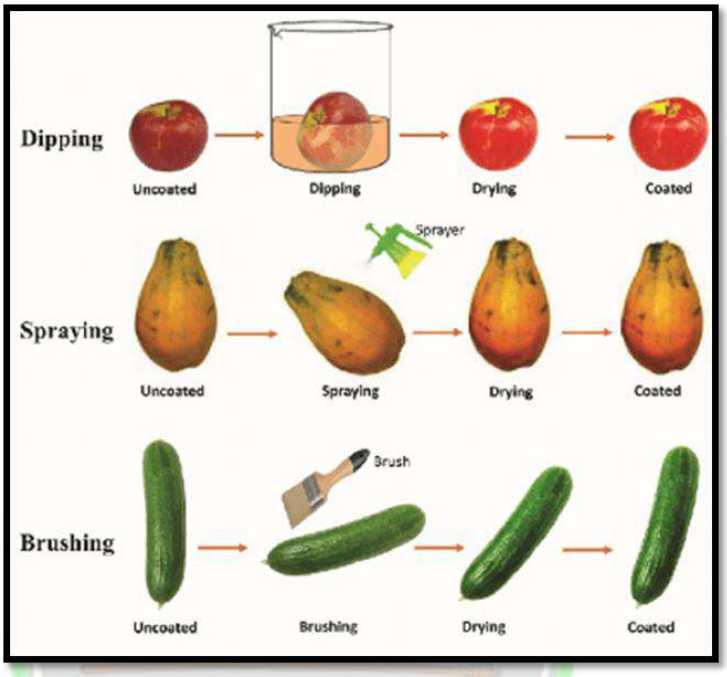
Cucumber

- Cucumbers are treated commercially with a coating formulation containing **2.5% o-phenylphenol (OPP)** to **reduce shrinkage and decay.**
- **Thiabendazole** was more effective, when these fungicides were applied to cucumbers in a **solvent wax formulation**.
- **Benomyl and carbendazim** dip treatments reduced several post-harvest diseases on cucumber, eggplant, pepper, and squash, but not those caused by *Alternaria*.

Cabbage

- Pre harvest sprays of **benomyl, thiabendazole, or dicarboximide** fungicides have reduced *Botrytis* decay during storage.
- **Pentachloronitrobenzene** dust has been a commercial treatment to control *Botrytis* on stored cabbage.
- **Thiabendazole and dicloran** dusts applied to cabbage before loading controlled *Botrytis* during a 7 month storage at 0ºC, but the incidence of *Alternaria* rot was not affected.
- A postharvest drench of **benomyl, thiabendazole, or a dicarboximide** fungicide over cabbage heads in bins reduced *Botrytis* rot considerably.

- A mixture of **thiabendazole or benomyl and iprodione** (dust or water spray) controlled both *Botrytis* and *Alternaria*.
- A smoke of **vinclozolin** provided good control of *Botrytis* and *Alternaria* on stored white cabbage.



ONION

- ***Botrytis* and *Sclerotinia* rots** during **cold storage** were substantially reduced by spraying the tops of the plants with **benomyl, thiophanate methyl, or vinclozolin** on the day before harvest.
- A postharvest dip of **sodium o-phenylphenate (SOPP)** controlled *Botrytis* and other storage rots.
- A **postharvest dip of benomyl (250-500 mg/l)** resulted in 96% marketable carrots after 5 months storage.

Potato

- **Thiabendazole** appeared to be somewhat more effective than benomyl for the control of dry rot.
- Several methods for application of **thiabendazole** to potatoes have been evaluated-dip, mist, spray, fog, dust, and thermal smoke.
- Dip and high liquid volume treatments gave most effective disease control.

- Black pit, a new postharvest disease of potatoes caused by ***Alternaria alternata*** was controlled by spraying the tubers with **1 g/l iprodione** before storage.

Yams

- Rotting of yams can be controlled by treating the tubers with **500-1000 ppm thiabendazole or benomyl** before storage.
- **Imazalil** was recommended as an alternative to the benzimidazoles when the decay-producing pathogens are resistant to these fungicides.
- In commercial use, **imazalil** was combined with dicloran to control ***Rhizopus spp.*** that was insensitive to **imazalil**.

METHODS OF CHEMICAL APPLICATION

Dipping

- For effective control of diseases chemical may be used with hot water at 55°C for about 10 minutes.
- The crop may be passed below shower of the diluted chemicals. This is called 'cascade' application.
- Use of chemical like citric acid to lower the pH of the solution along with fungicides seems more effective.
- In pineapple, infection occur commonly through the cut fruit stalk, therefore dipping cut end was found sufficient to control the disease, save pesticides solution and lower residues on the fruits.
- Eg: Root vegetables.

Spraying

- Spraying is more effective than dipping, because fungicide effectiveness is reduced if the crop has been washed and is still wet and many pesticide chemicals are formulated so that they are not in a solution, but rather in a fine suspension.
- This results in a concentration gradient in the tank between top (less concentration) and bottom (more) of the tank unless suspension frequently agitated.

Thin film of coating

- Breaking up the pesticide's solution into fine droplet and then giving them an electric charge to obtain uniformity of application.

- Principle is that the particle all have the same electrical charges hence, thus repel each other.
- These charges are attracted toward the crop and form uniform coating on the produce.
- Eg: Potato and crown rot of banana.

Dusting

- Dusting with wood ash and lime in case of yam.
- Fungicides along with talc on potato.

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CONGRESS GRASS – IMPACT ON AGRICULTURE

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Abstract

Congress grass an invasive weed introduced to India in the 1950s, poses a significant threat to Indian agriculture. It spreads rapidly, competing with crops for resources and releasing allelopathic chemicals that hinder plant growth. The weed degrades soil quality, reduces crop yields, and harms livestock due to its toxicity. It also causes severe allergic reactions in humans. Despite various control efforts including mechanical, chemical, and biological methods its management remains challenging. This article highlights the origin, impact, and control strategies for Congress grass, emphasizing the urgent need for integrated weed management and public awareness to safeguard agricultural productivity.

Key words: Congress grass, invasive weed, allelopathy,PL 480 program, soil degradation, parthenium ,soil toxicity, integrated weed management.

Introduction

Congress grass, scientifically known as *Parthenium hysterophorus*, is one of the most aggressive and harmful invasive weeds in India. Commonly called "Congress grass" or "gajar grass," this plant has had a significant negative impact on agriculture, biodiversity, and public health. Its history in India traces back to the mid-20th century and highlights how a small mistake in biosecurity can have long- term ecological consequences.

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Origins and Introduction to India

Parthenium hysterophorus is native to the tropical and subtropical regions of North and South America. It was never a part of India's natural flora. The plant made its way to the Indian subcontinent accidentally in the 1950s, specifically around 1955 through contaminated wheat grains imported from the United States under the PL 480 food aid program. The contaminated wheat was distributed across various regions in India, including Maharashtra, Madhya Pradesh, and Delhi, where the weed found favorable conditions to grow and spread rapidly. Since Congress grass thrives in open, sunny areas with disturbed soil, it soon began to flourish along roadsides, railway tracks, barren lands, and eventually into agricultural fields and pastures.

Rapid Spread and Establishment

By the 1970s, Congress grass had spread to several states, including Karnataka, Tamil Nadu, Andhra Pradesh, and Uttar Pradesh. Its ability to produce a large number of seeds (up to 25,000 per plant), which remain viable for many years, made it extremely difficult to control. The weed has no natural enemies in India, which allowed it to grow unchecked. It quickly began to outcompete native vegetation, degrade pasturelands, and invade crop- lands, leading to serious agricultural and ecological consequences.

Biological Characteristics:

Congress grass is a fast- growing, herbaceous plant that thrives in tropical and subtropical climates. It is characterized by finely divided, feathery leaves and small, white flowers. The plant produces a vast number of seeds up to 25,000 per plant which are dispersed by wind, water, and human activity, facilitating its rapid spread.

https://images.app.goo.gl/qJri4AcjmgCAMxqs9

Impact on Agriculture

Reduction in Crop Yields: Congress grass competes aggressively with crops for sunlight, water, and nutrients. Its allelopathic properties where it releases chemicals that inhibit the growth of surrounding plants further exacerbate this competition. Studies have shown that the presence of Congress grass can lead to yield reductions of up to 40% in crops such as wheat, rice, maize, and pulses.

Decline in Forage Availability: The weed's spread in pastures and grazing lands reduces the availability of nutritious fodder for livestock. Cattle and other herbivores tend to avoid grazing on Congress grass due to its toxicity, leading to a decrease in milk production and overall livestock health.

Soil Degradation: The allelopathic chemicals released by Congress grass not only suppress the growth of neighboring plants but also affect soil microorganisms essential for soil health. This disruption can lead to soil degradation, making it less fertile and less suitable for crop cultivation.

Health Implications

Human Health Risks: Direct contact with Congress grass can cause allergic reactions in humans, including skin rashes, dermatitis, and respiratory issues such as asthma. The plant's pollen is also a known allergen, exacerbating seasonal allergies.

Livestock Health: Congress grass contains toxic compounds that can cause severe health problems in livestock. Consumption of the plant can lead to symptoms ranging from mild digestive disturbances to severe organ damage and, in extreme cases, death.

Environmental Consequences

Biodiversity Loss: The aggressive nature of Congress grass allows it to outcompete native plant species, leading to a reduction in biodiversity. This loss affects the entire ecosystem, including pollinators, herbivores, and other flora and fauna dependent on native plants.

Disruption of Ecosystems: In natural habitats such as forests and grasslands, the dominance of Congress grass can alter ecosystem dynamics. Its spread can change the composition of plant communities, affecting the animals that rely on them for food and shelter.

Control and Management Strategies

Manual Removal: Early detection and manual uprooting of Congress grass can be effective in preventing its spread. Farmers and landowners are advised to wear protective gloves and masks when handling the plant to avoid allergic reactions.

Chemical Control: Herbicides can be used to control Congress grass; however, their application must be managed carefully to avoid harm to surrounding crops and the environment. Selective herbicides that target only the weed are preferred.

Biological Control: Introducing natural predators or pathogens specific to Congress grass is a promising approach. For instance, the leaf beetle *Zygogramma bicolorata* has been used in some regions to feed on the weed, though its effectiveness can vary.

Public Awareness and Education: Raising aware- ness among farmers and the general public about the dangers of Congress grass is crucial. Programs such as the "*Parthenium* Awareness Week" organized by the Indian Council of Agricultural Research (ICAR) aim to educate communities on identification, prevention, and control measures.

Conclusion

Congress grass poses a multifaceted threat to Indian agriculture, impacting crop yields, livestock health, soil fertility, and biodiversity. Addressing this issue requires a concerted effort from farmers, researchers, and policymakers. Through integrated management strategies and increased public awareness, it is possible to mitigate the adverse effects of Congress grass and protect India's agricultural heritage.

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INNOVATIVE NUTRITIONAL STRATEGIES FOR REVOLUTIONIZING POULTRY FARMING IN INDIA

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Introduction

India has emerged as a significant player in the global poultry industry, ranking third in egg production and fourth in broiler meat production. The poultry sector contributes approximately 1% to India's GDP and supports the livelihoods of over 25 million people, most of whom are small or marginal farmers. Despite its impressive growth trajectory, Indian poultry farming faces persistent challenges, particularly in the area of feed and nutrition, which accounts for 60–70% of total production costs. In a country where cost-efficiency and resource optimization are paramount, innovative nutritional strategies have become essential not only for enhancing productivity and profitability but also for ensuring sustainability and resilience against climate and market shocks.

Traditional poultry feed in India predominantly relies on soybean meal and maize, both of which are subject to high price volatility and regional shortages. Overdependence on these conventional ingredients has exposed the industry to global commodity market fluctuations, leading to increased production costs. Moreover, the conventional feed ingredients often fall short of meeting the nutritional requirements of genetically improved poultry breeds, particularly under the diverse agro-climatic conditions across India. Hence, a shift towards scientifically optimized and diversified feeding strategies is not just desirable it is imperative.

The concept of innovative nutrition in poultry extends far beyond simply tweaking feed compositions. It encompasses a broad spectrum of strategies including precision nutrition,

alternative protein sources, probiotic and phytogenic feed additives, nutrigenomics, in-ovo supplementation and the integration of digital tools like Artificial Intelligence (AI) and Internet of Things (IoT) in feed formulation and delivery systems. These approaches have shown promise in improving feed conversion ratio (FCR), enhancing gut health, strengthening immunity, reducing environmental footprint and ultimately increasing profit margins for poultry farmers.

Precision nutrition, for instance, enables farmers to tailor feed rations to the exact needs of poultry based on breed, age, performance targets and environmental factors. Tools like ICAR-CARI's MAKEFEED software have enabled the formulation of region-specific, cost-effective diets using locally available feed resources. Similarly, emerging feed ingredients such as insect meal (e.g., black soldier fly larvae), microalgae and single-cell proteins offer viable, eco-friendly alternatives to conventional protein sources and help bridge the protein deficit in poultry diets.

Furthermore, the prohibition of antibiotic growth promoters (AGPs) in many countries, including a growing push in India, has driven the need for natural growth promoters (NGPs) such as probiotics, prebiotics, synbiotics and phytogenics. For instance, DPR-EubioticA, developed by ICAR-DPR, is a herbal feed additive that has demonstrated efficacy in improving growth performance and gut health in broilers.

In parallel, advances in nutrigenomics the study of how feed nutrients influence gene expression are opening new frontiers in developing cost-effective diets that align with genetic potential, particularly in indigenous and improved dual-purpose breeds such as Vanaraja and Kuroiler. Additionally, technologies like in-ovo nutrient injection, where nutrients are delivered directly to the embryo, are being tested to enhance early chick development, immune competence and hatchability.

Finally, the integration of AI and IoT in poultry farming—ranging from smart feeders and climate sensors to real-time performance tracking and predictive analytics offers the ability to optimize feed usage, reduce waste and improve animal welfare, especially under heat stress and high-density farming conditions.

Innovative nutritional strategies are central to the transformation of India’s poultry sector. These solutions not only promise improved productivity and sustainability but also support India’s goals of rural development, food security and global competitiveness. A focused effort to scale these innovations through policy support, public-private partnerships, farmer education and

research dissemination will be critical in driving a nutritional revolution in Indian poultry farming.

Precision nutrition and formulation

As poultry farming in India continues to expand, improving feed efficiency and reducing production costs have become critical. Precision nutrition, a cutting-edge approach that tailors feed formulations to the specific needs of birds based on their genetics, growth stage, and environment, offers transformative potential. It ensures optimal performance, minimizes nutrient wastage, and enhances sustainability.

Precision nutrition focuses on delivering the exact nutrients required by birds at specific physiological stages. Unlike traditional feeding systems that follow generalized standards, this method uses real-time data and modeling to optimize feed formulations. The benefits include improved feed conversion ratios (FCR), better immune function, and reduced nitrogen and phosphorus excretion, leading to lower environmental impact.

In India, where feed costs account for 65–70% of total poultry production expenses, precision nutrition can significantly lower feed costs while maintaining or improving productivity. It also aligns with India's goals for sustainable livestock development and residue-free poultry products.

Formulation Tools and Techniques

Advanced formulation software, such as BestMix, INAPH, and Evonik AMINONIR, enable the integration of nutrient profiles, ingredient variability, and bird performance metrics to create customized feed blends. These tools are especially useful when incorporating region-specific feed ingredients like rice bran, bajra, and mustard cake, which are often underutilized due to variability in quality. Near Infrared Reflectance Spectroscopy (NIRS) technology plays a key role in precision feed formulation by providing rapid, accurate assessment of feed ingredient composition. It allows nutritionists to account for fluctuations in nutrient content and adjust rations accordingly.

Application in Indian Context

Implementing precision nutrition in India requires capacity building, infrastructure development, and tech adoption at the farm level. Large integrators and commercial feed mills are beginning to adopt precision tools, but small and medium-scale farmers need support through government extension programs, mobile advisory services, and subsidies on diagnostic tools.

Furthermore, integrating precision nutrition with IoT-based sensors and AI can help monitor bird behaviour, health, and feed intake in real time, enabling dynamic adjustments to diets. This approach supports both efficiency and welfare, which are increasingly valued in global markets. By shifting to precision nutrition and formulation, India can modernize its poultry sector, enhance profitability, and contribute to sustainable agriculture and food security.

Alternative protein sources and functional feed ingredients

The poultry industry in India is expanding rapidly, yet the escalating cost and limited availability of conventional protein sources like soybean meal and fishmeal pose significant constraints. To ensure sustainable and cost-effective growth, the adoption of alternative protein sources and functional feed ingredients is vital for modernizing poultry nutrition.

Alternative Protein Sources

India's diverse agro-ecological zones offer several underutilized and sustainable protein alternatives. Insect meals, particularly from black soldier fly larvae (BSFL), are gaining popularity due to their high protein content (40–50%), favourable amino acid profile, and low environmental footprint. BSFL can be reared on organic waste, supporting a circular economy. Single-cell proteins (SCPs) derived from microbes such as yeast (*Saccharomyces cerevisiae*), fungi and algae are another promising solution. SCPs are rich in protein, vitamins, and enzymes, and can be produced using waste substrates like molasses or effluents. Leaf meals from moringa, Mulberry, Leucaena, azolla and duckweed are rich in protein, antioxidants, and phytochemicals. These are easily cultivable across India and can be incorporated into broiler and layer diets to partially replace costly commercial protein sources.

Functional feed ingredients

Functional feed ingredients not only meet nutritional requirements but also deliver health-promoting benefits. Omega-3 fatty acid sources such as flaxseed and microalgae improve meat quality and immune response in poultry, addressing consumer demand for functional foods. Herbal supplements, such as turmeric (curcumin), garlic, and fenugreek, have demonstrated anti-inflammatory, antimicrobial, and growth-promoting properties. These are especially relevant in the Indian context due to their cultural acceptance and local availability. Yeast-derived products, like beta-glucans and nucleotides, serve as immune-modulators and gut health enhancers, reducing the need for antibiotics and improving feed efficiency.

Implementation strategies

For successful adoption, India must support research on regionally available feed resources, invest in pilot-scale production units for insect protein and SCPs, and promote awareness through extension programs. Government policies should encourage public-private partnerships and offer incentives for antibiotic-free, functional feed production. Integrating alternative proteins and functional ingredients into poultry diets can make Indian poultry farming more resilient, affordable, and globally competitive while meeting both economic and environmental goals.

Feed additives for gut health, immune-modulation and performance

India's poultry sector is among the fastest-growing globally, yet it faces escalating challenges, including antibiotic resistance, disease outbreaks, and pressure to reduce production costs. Innovative feed additives that enhance gut health, support immune function, and improve performance are emerging as critical tools to revolutionize poultry nutrition in a sustainable and antibiotic-free manner.

Gut health: Probiotics, prebiotics and enzymes

Gut health is central to nutrient absorption and disease resistance. Probiotics, such as *Lactobacillus* and *Bacillus subtilis*, help maintain a balanced gut microbiota and inhibit pathogenic bacteria. Prebiotics, including mannan-oligosaccharides (MOS) and fructo-oligosaccharides (FOS), serve as substrates for beneficial microbes, enhancing gut integrity. Enzymes like phytase and xylanase improve nutrient digestibility and reduce anti-nutritional factors in Indian feed ingredients like rice bran and pearl millet.

Immunomodulation: Phytogenics and organic acids

With rising restrictions on antibiotic growth promoters (AGPs), phytogenic feed additives (PFAs) plant-based compounds such as essential oils, saponins and alkaloids have gained attention. Indian herbs like neem, tulsi and turmeric show strong antimicrobial and antioxidant activity, enhancing the immune system and reducing inflammatory responses. Organic acids, such as formic and lactic acid, lower gut pH, creating an unfavourable environment for pathogens. These additives also improve nutrient absorption and immune competence, especially in broilers raised under sub-optimal field conditions.

Performance enhancers: Amino acid optimizers and mycotoxin binders

Feed-grade amino acids like methionine and lysine improve growth and feed conversion

when precisely balanced. Mycotoxin binders, particularly essential in Indian climates, protect poultry from toxin-induced performance losses and immune suppression due to contaminated feed ingredients.

Implementation pathways

To promote adoption, India must strengthen extension services and training programs through Krishi vigyan kendras (KVKs), support indigenous additive development and incentivize quality control in feed manufacturing. Policies that encourage antibiotic-free poultry production can further drive demand for these innovations. By incorporating scientifically validated feed additives, India's poultry industry can enhance bird health, reduce mortality and ensure sustainable and residue-free production, aligned with global standards.

In-ovo injection and nutrigenomics

India's rapidly expanding poultry industry faces challenges related to early chick mortality, feed efficiency and disease susceptibility. Advanced nutritional interventions like in-ovo injection and nutrigenomics offer transformative strategies to enhance poultry productivity and resilience from the embryonic stage. In-ovo injection involves delivering nutrients, probiotics or immune-stimulants directly into the egg during incubation. This technique enhances embryonic development, hatchability, gut health and immune response. Nutrients such as amino acids, vitamins (e.g., vitamin E), and prebiotics (e.g., MOS and FOS) are commonly used. In the Indian context, adopting this technique in large hatcheries can improve chick viability, reduce post-hatch stress and enhance early growth performance critical factors for commercial broiler success.

Nutrigenomics, the study of how nutrients influence gene expression, opens a new frontier in precision poultry nutrition. It helps in formulating diets that regulate genes responsible for growth, immunity and metabolism. For example, feeding omega-3 fatty acids or selenium-enriched diets can up-regulate antioxidant enzymes and immune genes, improving disease resistance and reducing the need for antibiotics. The integration of nutrigenomic insights into feed formulation allows the development of genotype-specific diets. This is particularly relevant for India, where indigenous breeds and crossbreds coexist. Modified diets can improve feed efficiency, meat quality and animal welfare, while reducing environmental impact.

For implementation, India must invest in infrastructure, research and development (R&D) and technical training. Collaborations between hatcheries, feed manufacturers and research

institutions like ICAR and IVRI can facilitate field trials and commercialization of these technologies. Subsidies for nutritionally enhanced hatching programs and incentives for genomics research can accelerate adoption. By embracing in-ovo and nutrigenomic strategies, India can transition from conventional to science-driven poultry nutrition, unlocking genetic potential and boosting sustainable production.

Region-specific and low-cost formulations

The Indian poultry industry, one of the largest globally, faces significant challenges in feed cost management, which comprises nearly 70% of total production expenses. To ensure profitability and sustainability, region-specific and low-cost feed formulations are emerging as innovative strategies to transform the sector. India's diverse agro-climatic zones produce a wide range of locally available feed resources such as broken rice, maize, pearl millet (bajra), sorghum (jowar), rice bran and oilseed cakes. Utilizing these regional by-products can drastically reduce dependency on expensive conventional ingredients like soybean meal and maize. For instance, in southern India, groundnut cake and tapioca residues are abundant, while in northern states, mustard cake and wheat bran are readily available.

Moreover, formulating feed based on nutrient availability rather than ingredient composition can further reduce costs. Advanced feed evaluation techniques like near infrared reflectance spectroscopy (NIRS) allow real-time analysis of local ingredients, enabling precise formulation of balanced diets at the farm level. The inclusion of non-conventional feed resources (NCFRs) such as azolla, moringa leaves and fermented leaf meals/ leaf meal mixture, agro-wastes also provides protein-rich, low-cost alternatives for rural poultry farming. These locally cultivable inputs can be processed into feed supplements to reduce reliance on commercial concentrates.

For widespread adoption, training and demonstration programs are critical. KVKs and state agricultural, veterinary and animal science universities can play a central role in disseminating low-cost formulation techniques and promoting the use of feed formulation software like INAPH or Bestmix tailored for Indian conditions. By embracing region-specific and economically viable feed strategies, India can empower small and medium poultry farmers, reduce feed imports and boost rural livelihoods. These innovations not only lower production costs but also support a more resilient and self-reliant poultry sector.

Integration with technology: AI, IoT, and digital tools

The poultry industry in India, while expanding rapidly, faces persistent challenges related to feed efficiency, disease management and rising production costs. Integrating innovative nutritional strategies with emerging technologies such as artificial intelligence (AI), the internet of things (IoT) and digital tools presents a transformative pathway for the sector.

AI-driven feed formulation tools can optimize diets by analyzing large datasets related to bird genetics, age, health status and environmental conditions. Machine learning models can continuously refine nutritional plans to improve FCR and reduce wastage. These tools help tailor micronutrient and amino acid profiles for enhanced productivity and bird welfare.

IoT-based smart sensors can monitor feed intake, water consumption and environmental parameters in real time. This enables precision feeding systems, which adjust feed delivery based on bird behaviour and health indicators, preventing over or under-feeding. Integration with automated feeding systems ensures consistent nutrient delivery and reduces human error.

Digital platforms and mobile applications now allow farmers especially smallholders in rural India to access real-time advice on feed composition, disease alerts and market trends. These platforms can integrate with wearable tech or smart poultry houses to provide alerts on nutritional deficiencies or feed-related illnesses.

To successfully implement these technologies, India must focus on capacity building, affordable technical solutions and rural connectivity. Government programs like digital India and initiatives through the national livestock mission (NLM) can support the adoption of AI and IoT at the farm level. Public-private collaborations can help local start-ups deliver tech-enabled nutritional solutions at scale.

When nutritional innovations are combined with smart technology, India's poultry sector can become more sustainable, data-driven and resilient. This integration offers not just improved productivity, but also a pathway to precision poultry farming, securing food and economic security for millions.

Sustainability and waste-to-protein

India's growing demand for poultry products places increasing pressure on feed resources, which constitute 60–70% of production costs. To revolutionize poultry farming, sustainable nutritional strategies especially those utilizing waste-to-protein innovations are essential for reducing environmental impact and ensuring long-term viability.

One of the most promising approaches is the conversion of agro-industrial and food waste into high-value poultry feed ingredients. India generates substantial food processing residues such as fruit pulp, brewery waste and spent grains. Through controlled fermentation and drying, these by-products can be transformed into nutrient-rich feed, lowering input costs while minimizing environmental waste.

Another breakthrough is the use of insect-based protein, particularly black soldier fly larvae (BSFL), which can be reared on organic waste. BSFL meal offers a protein content of over 40% and is a sustainable alternative to soybean meal and fishmeal. With minimal land and water requirements, insect farming aligns well with India's rural economy and circular agriculture models.

Algae-based feeds, especially microalgae like Spirulina, also provide a sustainable, high-protein supplement with essential fatty acids and pigments. They can be cultivated using wastewater, making them a dual-purpose solution for nutrient recycling and protein production (Becker, 2007).

To enable adoption, India must develop policy frameworks and investment incentives for decentralized waste processing units and insect farming clusters. Training programs for farmers and integration of these innovations into mainstream feed supply chains are crucial. Public-private partnerships and support from KVKs can accelerate grassroots implementation. By converting waste into value-added poultry nutrition, India can achieve resource efficiency, reduce carbon footprint and build a resilient poultry sector. These strategies not only ensure food security but also contribute to national goals on waste management and sustainability.

Implementation pathways in Indian context

Poultry farming in India is a vital contributor to the agricultural economy, yet it faces challenges such as rising feed costs, disease outbreaks and suboptimal productivity. Innovative nutritional strategies, when tailored to Indian conditions, can significantly enhance poultry health, productivity and profitability. One transformative approach is precision nutrition, which involves formulating diets based on the specific requirements of birds at different growth stages. This reduces feed waste and optimizes nutrient intake. Indian poultry farms can adopt region-specific feed formulations using locally available ingredients like maize, pearl millet and broken rice to reduce dependency on soybean meal and corn.

Use of phytogenic feed additives (PFAs) plant-based compounds like essential oils, herbs and spices is gaining traction as a natural alternative to antibiotics. PFAs improve gut health, immunity and feed efficiency without the risk of antimicrobial resistance. India, with its rich biodiversity, can leverage indigenous herbs like tulsi, neem and turmeric for cost-effective PFA development. Fermented feed technologies, such as the use of probiotics and enzyme-supplemented feeds, enhance nutrient digestibility and support gut microbiota. These can be integrated into small and medium farms through training and partnerships with feed companies. To implement these strategies effectively, capacity building and policy support are essential. Extension services must train farmers in new feed practices and quality control. Government incentives for indigenous feed production, PFA research and public-private partnerships can accelerate adoption. Additionally, digital platforms can help disseminate best practices and real-time nutritional advice to farmers. India's poultry sector, poised for rapid growth, can achieve sustainability and global competitiveness through targeted nutritional innovations. Aligning these with local resources and farmer education will ensure long-term transformation.

Conclusion

Innovative nutritional strategies hold immense potential to transform poultry farming in India by enhancing productivity, sustainability and profitability. With rising feed costs and increasing demand for antibiotic-free, high-quality poultry products, there is a pressing need to adopt science-driven, resource-efficient nutrition practices. Approaches such as precision nutrition, region-specific feed formulation and the use of alternative protein sources like insect meal and single-cell proteins can drastically reduce input costs and environmental impact.

Furthermore, integrating functional feed additives such as probiotics, phytogenics and enzymes promotes gut health and immunity, reducing dependency on antibiotics. Cutting-edge technologies like in-ovo nutrient injection and nutrigenomics offer novel ways to unlock the genetic potential of poultry. Digital tools, IoT-based monitoring and AI-powered feed formulation can further enhance feed efficiency and animal welfare. To ensure widespread adoption, India must invest in research, farmer training and infrastructure that supports local feed innovation. Public-private partnerships, supportive policies and accessible extension services will play a crucial role in scaling these solutions. By embracing these nutritional advancements, India can build a resilient, self-reliant and globally competitive poultry sector that meets the demands of both producers and consumers in a sustainable manner.

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GOLDEN GRAINS OF THE FUTURE: THE MODERN COMEBACK OF MILLETS

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Introduction

In India, out of 141 million hectares of farming land, rainfed farming is done on 85 million hectares in 177 districts. This means about 60% of farming in India depends only on rain. Rainfed farming gives 44% of the country's food grains. It also grows 75% of pulses and more than 90% of crops like sorghum, millets, and groundnut, mostly in dry areas. Millets need very little water to grow. Crops like sorghum, pearl millet, and finger millet use less than 25% of the water needed for sugarcane and banana, and only 30% of what rice needs (Table 1). In the future, when there may be less water

and food, millets can help keep us safe from hunger.

What are Millets?

Millets, also known as "nutricereals" in India, are a group of small-grained cereals that are highly nutritious and have been grown in India for a long time, mainly in areas that depend on rainfall, often by small and poor farmers. They were once a staple food in many Indian homes before rice and wheat became more common. Today, millets are becoming popular again because they are rich in fibre, protein, and important nutrients like iron, calcium, and magnesium. They are naturally gluten-free and have a low glycemic index, making them a healthy choice for people with diabetes and digestion problems. In India, millets are divided into two types: major millets like sorghum and pearl millet, and minor millets like little millet, barnyard millet,

Table 1. Comparative rainfall requirement of various crops

Crop Name	Minimum Rainfall Requirement (mm)
Sugarcane	2000
Banana	2000
Rice	1200
Chillis	600
Cotton	600
Mustard	400
Wheat	400
Pearl Millet (Bajra)	200
Finger Millet (Ragi)	400
Foxtail Millet	400
Kodo Millet	450
Little Millet	300
Barnyard Millet	450
Browntop Millet	300
Proso Millet	350

kodo millet, foxtail millet, finger millet, and proso millet. India is the largest producer of millets in the world, growing about 18 million tons every year on 60 million acres of land. States like Rajasthan, Karnataka, Maharashtra, Uttar Pradesh, and Tamil Nadu are the main millet-growing areas. To encourage their use, the Government of India declared 2018 as the "National Year of Millets," (IYOM) and the United Nations declared 2023 as the "International Year of Millets." Because they grow well in tough conditions and need little water, millets are also good for the environment.

Importance of Millets in Farmers' Lives

Millets cultivation holds great significance in supporting the livelihoods of small and marginal farmers across India, particularly in dry and rainfed regions where water is scarce and other crops often fail to grow well. These hardy grains are uniquely suited to such challenging environments because they require very little water, can thrive in poor and less fertile soils, and are highly resilient to harsh climatic conditions like drought and high temperatures. This makes millets an ideal crop for low-input farming, especially for farmers who cannot afford expensive irrigation systems, chemical fertilizers, or other costly agricultural inputs. In recent years, with increasing awareness about the health benefits of millets—such as being gluten-free, low in calories, and beneficial for managing diabetes—the demand for millets has steadily risen in urban and rural markets alike. This growing popularity has provided farmers with better opportunities to earn higher incomes by selling their produce. It also plays a crucial role in making farming more sustainable and environmentally friendly by conserving water resources and improving soil health. In summary, millet cultivation not only sustains the livelihoods of vulnerable farmers but also supports the larger goals of nutrition, economic stability, and ecological balance in Indian agriculture.re farmers to grow millets for better health, income, and environmental protection.

Types of Millets

Millets belong to the Poaceae family, commonly known as the grass family. They consist of several species, each with distinct nutritional profiles, making them versatile and valuable grains. Millets are broadly classified into two main categories: Major Millets and Minor Millets (Table 2).

Table 2: Common millets with local names & scientific names and nutritional highlights and typical uses.

S. No.	Common/ Indian Name	Common Millet Name	Scientific Name	Key Nutritional Highlights	Common Uses	Remarks
Major Millets (Neutral grains)						
1.	Jowar	Sorghum	*Sorghum bicolor*	Good in dietary fiber, protein, iron, and antioxidants, making it a nutritious gluten-free grain	Used to make flatbreads, porridge, animal fodder, and gluten-free flour products	Drought-tolerant crop known for its resilience and high adaptability to arid climates
2.	Bajra, Bajri,	Pearl Millet	*Pennisetum glaucum*	Rich in fiber, protein, iron, calcium, and magnesium	Commonly used in rotis, porridges, and fermented dishes.	Drought-tolerant; grows well in dry areas.
3.	Ragi, Nachni	Finger Millet	*Eleusine coracana*	Exceptionally rich in calcium, iron, antioxidants, and essential amino acids	Used in rotis, porridge, and malted beverages	Requires moderate rainfall; rainfed regions.
4.	Cheena, Broomcorn or Hog Millet	Proso Millet	*Panicum miliaceum*	Contains protein, fiber, magnesium, and phosphorus.	Used in pilafs, bread, and porridges	Low water requirement; grows quickly.
Minor Millets (Positive grains)						
1.	Kangni, Korra, Thinai	Foxtail Millet	*Setaria italica*	High in dietary fiber and minerals like iron and calcium	Used in upma, porridge, dosa, and idli.	Grows well in dry, light soils.
2.	Kodra, Varagu	Kodo Millet	*Paspalum scrobiculatum*	Contains iron, zinc and dietary fiber	Used in fermented dishes, upma, and porridge.	Tolerates poor soils and moderate rainfall.

3.	Kutki, Samai	Little Millet	*Panicum sumatrense*	Contains iron, phosphorus, protein, and fiber	Ideal for idli, dosa, and porridge	Performs well under rainfed conditions.
4.	Jhangora, Sanwa, Udalu	Barnyard Millet	*Echinochloa colona*	Rich in protein, fiber, calcium, phosphorus	Used in khichdi, pulao, and fasting recipes.	Needs moderate rainfall; short growing period.
5.	Korale, Saame	Brown Top Millet	*Urochloa ramosa*	Highly rich in protein, fiber, iron, magnesium	Used in porridge, upma, idli, dosa	Grows with very low water; ideal for drylands.

Nutritional Value of Millets

Millets are much more nutritious than rice and wheat (Negative grains). They have a lot more minerals and fibre. Some millets have up to 50 times more fibre than rice. A 100-gram serving of raw millets gives about 378 calories. Millets are full of good things like carbohydrates, protein, fibre, vitamins, minerals, and antioxidants. They also have B vitamins like niacin (B_3), thiamine (B_1), and riboflavin (B_2) (Table 3). These vitamins help our body make energy, keep our nerves healthy, and repair cells. Because of these health benefits, millets are becoming more popular all over the world as a healthy and eco-friendly food.

Table 3: Nutritional Value of millets vs Rice & Wheat: Nutrients & fibre present in 100 grams of Grains

Source: Dr Khader Vali

Processing of Millets

Processing of millets means converting raw grains into forms that are easy to cook and eat, which also improves their taste, texture, and shelf life. Millets can be broadly classified into two types—those with husk layers and those with only a seed coat. For millets with husks, the process begins with cleaning to remove dust, stones, and other unwanted materials. The cleaned grains are then destoned and dehusked using machines, and the separated husk is blown off. The mixture of dehusked and unhusked grains is passed through a separator, and the unhusked ones are sent back for further dehusking. Once fully dehusked, the grains are polished in stages to reduce breakage, although polishing can lower their fibre and nutrient content—so unpolished millets are considered healthier. The polished grains are then sifted to remove broken pieces, and

intact whole grains, known as "head grains," may be colour-sorted (optional) before weighing and packing. Finally, processed millets or millet flour are packed in clean, airtight bags and stored in cool, dry places to keep them fresh and safe from insects and moisture.

Group	Grains	Fiber (g)	Protein (g)	Minerals (g)	Carbohydrate (g)	Carotene (mg)	Iron (mg)	Calcium (g)	Phosphorous (g)	Thiamine (B_1) (mg)	Riboflavin (B_2) (mg)	Niacin (B_3) (mg)	Ratio of Carbohydrate to Fiber
Negative grains	Wheat	1.20	11.80	1.50	76.20	64.00	5.30	0.05	0.32	0.35	0.17	5.00	63.50
	Rice	0.20	6.90	0.60	79.00	0.00	1.00	0.01	0.11	0.06	0.06	1.20	395.00
Neutral grains	Sorghum	1.30	10.40	1.60	72.40	47.00	4.10	0.03	0.28	0.37	0.13	1.80	55.70
	Pearl Millet	1.20	11.60	2.30	67.10	132.0	8.00	0.05	0.35	0.33	0.25	2.30	55.90
	Finger Millet	3.60	7.10	2.70	72.70	42.00	5.40	0.33	0.27	0.42	0.19	1.10	20.20
	Proso Millet	2.20	12.50	1.90	68.90	0.00	5.90	0.01	0.33	0.20	0.18	2.30	31.30
Positive grains	Foxtail Millet	8.00	12.30	3.30	60.60	32.00	6.30	0.03	0.29	0.59	0.11	0.70	7.60
	Kodo Millet	9.00	6.20	2.60	65.60	0.00	2.90	0.04	0.24	0.33	0.09	2.00	7.30
	Little Millet	9.80	7.70	1.50	65.50	0.00	2.80	0.02	0.28	0.30	0.07	1.50	6.70
	Barnyard Millet	10.00	6.20	4.40	65.50	0.00	2.90	0.02	0.28	0.31	0.08	1.50	6.60
	Browntop Millet	12.50	11.50	4.21	69.37	0.00	0.65	0.01	0.47	3.20	0.03	18.5	5.50

How Should Millets Be Stored?

Proper storage of millets is very important to keep them fresh, nutritious, and safe from insects and moisture. After harvesting and processing, millets should be stored in clean, dry, and airtight containers or bags to prevent exposure to air and humidity. The storage place should be cool and well-ventilated to avoid heat and dampness, which can spoil the grains. It is best to keep millets away from direct sunlight and moisture to prevent mold growth. Regularly checking the stored millets for any signs of insects or damage helps in taking early action to protect the grains. Using natural methods like neem leaves or storing grains with dried chillies can help keep pests away without harming the millets. Following these simple storage tips ensures that millets stay healthy and tasty for a long time.

Value Addition of Millets

Numerous value-added products have been developed from small millets to enhance their utilization and offer farmers diversified opportunities beyond traditional recipes. These include bakery products, pasta, flaked and puffed snacks, as well as instant food mixes. For instance, puffed products such as sorghum puffs, foxtail millet puffs, and pearl millet (bajra) puffs are created by expanding the grains while retaining their original shape, resulting in crispy snacks with varying shelf lives when properly packaged.

Extruded flakes, ready-to-eat snacks made by cooking and shaping millet grains using a twin-screw extruder and roller flaker, provide convenient options for consumers. Instant food mixes like sorghum idli, upma, dosa, pongal, and millet laddu mixes deliver quick, hygienic meals that are easy to prepare. Millet-based pasta combines millet semolina with a small proportion of wheat flour to improve texture, compensating for millet's naturally low gluten content.

Additionally, millet cookies and cakes made from pearl millet, finger millet, and foxtail millet flours—enhanced with ingredients like sugar, milk solids, fats, eggs, and natural flavorings—are gaining popularity. These innovative products not only boost millet consumption by offering nutritious and appealing alternatives suited for modern lifestyles but also support the livelihoods of millet farmers.

Health Benefits of millets

Millets are tiny grains that are very good for your health. They are full of nutrients like **niacin** (good for skin and organs) and **beta-carotene** (especially in dark-colored millets), which

turns into **vitamin A** in your body. This helps you fight illness and keeps your immune system strong.

The main health benefits of eating mill

- **Controls Blood Sugar**

Millet is a low-glycemic index (GI) and non-acid-forming food due to its low simple carbohydrate and high complex carbohydrate content; hence, its flour requires more time in the digestive process. means they do not cause a sudden rise in blood sugar. They have special types of carbs and lots of **fiber**, making them a good food for people with diabetes who can better control their blood sugar levels by eating meals with a low glycemic index (GI).

- **Improves Digestion**

Millets are rich in insoluble and soluble fiber. Insoluble fiber promotes the healthy microorganisms in your intestines, which helps with **good digestion** and keeps your stomach healthy. The fiber also helps in making your poop regular and lowers the chance of colon cancer.

- **Keeps Your Heart Health**

The fiber in millets may also raise your "good" cholesterol levels and lower your triglycerides, which is good for your heart health. Millets also have **magnesium**, a mineral that helps prevent heart problems like **heart failure**.

- **Slows Down Aging**

Millets have natural plant compounds like tannins, phenols, and phytates that help protect your body's cells. These compounds can lower the risk of diseases such as diabetes, high blood pressure, and high cholesterol, which often happen as people get older. Millets, especially the darker ones, also have a lot of beta-carotene. This is a natural substance that acts as an

antioxidant and turns into vitamin A in your body. It helps protect your eyes and keeps your body safe from harmful substances called free radicals.

- **Builds Healthy Cells**

Some millets, like finger millet (ragi), are full of B vitamins, which are very important for your brain, nerves, and red blood cells. One of these vitamins, niacin (vitamin B3), helps your body do many important jobs—over 400 processes in total! Niacin is needed for a strong immune system, healthy skin, and proper function of your organs. B vitamins also help your body make new and healthy cells, which keeps you feeling strong and well.

Conclusion

Millets, often referred to as "**smart foods**," are not only rich in nutrients but also play a crucial role in sustainable agriculture and cultural heritage. They are full of nutrients and help keep us healthy. Millets can grow well even in dry places where there is very little water and the soil is not very good. This makes them perfect for farmers who live in such areas and cannot grow other crops easily. Because millets need less water and care, they are good for protecting nature and saving water. Many people are now learning about the health benefits of millets, so they are becoming popular again in our daily meals. There are also many new and tasty products made from millets, like snacks, pasta, and cakes, which more people enjoy. Growing more millets can help farmers earn better money and also make sure there is enough food for everyone. At the same time, millets help take care of our environment, so they are a smart choice for farming in the future.

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MANAGING HEALTH IN RAS: SYSTEM TYPES, COMMON DISEASES, TREATMENT APPROACHES AND BIOSECURITY STRATEGIES

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Introduction

RAS (Recirculatory Aquaculture System) is one of the most advanced Aquaculture System. Recirculatory Aquaculture System (RAS) is a technology where water is recycled and reused after mechanical and biological filtration and removal of suspended matter and metabolites. This method is used for high- density culture of various species of fish, utilizing minimum land area and water. It is an intensive high density fish culture unlike other aquaculture production systems. Instead of the traditional method of growing fish outdoors in open ponds and raceways, in this system fish are typically reared in indoor/outdoor tanks in a controlled environment.

Recirculating systems filter and clean the water by recycling it back to fish culture tanks. The technology is based on the use of mechanical and biological filters and the method can be used for any species grown in aquaculture. New water is added to the tanks only to make up for splash out, evaporation and that used to flush out waste materials. The reconditioned water circulates through the system and not more than 10% of the total water volume of the system is replaced daily.

In India, the adoption of RAS offers significant advantages such as enhanced control over water quality, reduction in disease transmission from outside sources, and the ability to culture high-value species in a controlled environment.

However, despite these benefits, effective disease management remains paramount to ensure sustainable production. The high-density stocking and limited water exchange typical of RAS can create stressful conditions that may result in outbreaks of various diseases also Indian

RAS operations face unique challenges due to regional climatic variations, water source quality, and limited access to specialized resources. These factors underscore the need for tailored disease management protocols that incorporate precise chemical treatment dosages, environmental monitoring, and biosecurity practices to ensure fish health and system productivity. These diseases broadly fall into the following categories.

- **Bacterial diseases** like Columnaris, Aeromoniasis, and Streptococcosis;
- **Viral infections** including Infectious Hematopoietic Necrosis (IHN), Koi Herpesvirus (KHV), and Viral Nervous Necrosis (VNN);
- **Fungal diseases** such as Saprolegniasis;
- **Parasitic infestations** including Ichthyophthiriasis and Trichodiniasis;
- **Environmental and nutritional disorders** like Gas Bubble Disease and nutritional deficiencies.

Bacterial Diseases and Their Treatment in RAS

Bacterial infections are among the most common and economically significant diseases affecting fish in Recirculating Aquaculture Systems (RAS) across India. The primary bacterial pathogens that challenge RAS operations include **Columnaris disease**, **Aeromoniasis (Motile Aeromonas Septicemia)**, and **Streptococcosis**. Effective management of these infections requires a combination of chemical treatments, biosecurity, and optimal husbandry practices to maintain fish health and productivity.

1. Columnaris Disease

Etiology: Caused by the Gram-negative bacterium **Flavobacterium columnare**, Columnaris disease is frequently observed in Indian RAS systems, particularly under stressed conditions such as poor water quality or elevated stocking densities.

Symptoms: The disease manifests as whitish to yellowish lesions on the skin, fins, and gills, often with a characteristic cotton-like appearance. Infected fish may exhibit lethargy, reduced feeding, and respiratory distress. If untreated, it can lead to high mortality rates.

Operational Measures*:* Maintaining high water quality with dissolved oxygen above 5 mg/L, stable temperature, and reducing organic load are critical. Lowering stocking densities and promptly removing infected fish help curb disease spread. Biosecurity protocols such as disinfecting equipment and quarantine of new stocks further mitigate risks.

2. Aeromoniasis (Motile Aeromonas Septicemia)

Etiology: Caused by bacteria of the genus **Aeromonas**, mainly *Aeromonas hydrophila*, this systemic infection affects freshwater species farmed in RAS.

Symptoms: Fish present with hemorrhagic ulcers, fin rot, abdominal distension, and exophthalmia. Mortality can be rapid and severe if untreated.

Operational Measures*:* Maintaining water quality parameters within optimal ranges and minimizing handling stress are essential. Regular monitoring for early symptoms and implementation of strict biosecurity protocols prevents outbreaks.

3. Streptococcosis

Etiology: This disease is mainly caused by **Streptococcus agalactiae**, a Gram-positive bacterium increasingly reported in Indian RAS fish species, including tilapia and catfish.

Symptoms: Infected fish show erratic swimming, exophthalmia, swollen abdomen, and hemorrhages at the base of fins. Nervous signs and sudden death are common.

Operational Measures*:* Reducing stocking density, ensuring good water exchange rates within the RAS, and decontaminating the system components between production cycles help manage disease incidence. Early diagnosis and timely treatment remain crucial.

Key Management Practices for Bacterial Disease Control in RAS

- **Water Quality Management**.
- **Biosecurity**
- **Stocking Density**
- **Withdrawal Periods**
- **Regular Monitoring**

Viral Diseases and Their Management in RAS

Viral diseases represent a significant challenge in Recirculating Aquaculture Systems (RAS) in India due to their high transmissibility and limited direct treatment options. The most prevalent viral infections encountered in Indian RAS setups are **Infectious Hematopoietic Necrosis (IHN)**, **Koi Herpesvirus (KHV)**, and **Viral Nervous Necrosis (VNN)**. Understanding their virology, clinical manifestations, and management strategies is crucial for minimizing losses and ensuring system sustainability.

Common Viral Diseases in Indian RAS

- **Infectious Hematopoietic Necrosis (IHN):** Caused by a rhabdovirus, IHN primarily affects salmonids but can infect other species under stress. Clinical signs include darkening of the skin, exophthalmia, abdominal swelling, and erratic swimming. Mortality rates may reach 90% in severe outbreaks.
- **Koi Herpesvirus (KHV):** A highly contagious virus affecting common carp and koi carp. Symptoms include lethargy, sunken eyes, gill necrosis, excessive mucus production, and rapid mortality. KHV can remain latent and reactivate under stress conditions.
- **Viral Nervous Necrosis (VNN):** Caused by betanodaviruses, VNN primarily affects marine and brackish water species. Clinical signs are abnormal swimming behavior (corkscrew motion), anorexia, and neurological symptoms leading to high mortality, especially in larvae and juveniles.

Management and Preventive Measures

Because no specific antiviral drugs are currently approved or widely effective for fish viral diseases, management is heavily reliant on prevention, early detection, and strict biosecurity:

- **Biosecurity Protocols**
- **Quarantine**
- **Use of Certified Disease-Free Seeds**.
- **Environmental Management**
- **Vaccination**.
- **Supportive Care**

Challenges and Importance of Early Detection

Closed systems like RAS are prone to rapid disease spread due to high stocking densities and recirculation of water. Viral pathogens can persist in biofilters and sediments, complicating eradication efforts. Therefore, early detection through routine health surveillance, molecular diagnostics (PCR assays), and prompt removal of infected fish are vital to prevent large-scale mortality.

Indian aquaculture disease control frameworks, including those by ICAR-CIFA and CIBA, emphasize integrated disease management incorporating these preventive strategies for sustainable viral disease control in RAS setups.

Fungal Diseases and Treatment Approaches

Saprolegniasis: Overview and Etiology

Saprolegniasis is the most common fungal infection affecting fish in Recirculating Aquaculture Systems (RAS) across India. It is caused by *Saprolegnia spp.*, a water mold belonging to the class Oomycetes. This pathogen typically invades fish suffering from physical injury, stress, or compromised immune status, and is especially prevalent during egg incubation stages or when water quality deteriorates.

Symptoms and Predisposing Conditions

Clinically, Saprolegniasis is characterized by *cotton-like white or greyish fungal growths* on the skin, fins, gills, and eggs. Infected fish may display lethargy, anorexia, and increased mortality in severe cases. Outbreaks are often associated with poor water quality, low dissolved oxygen, fluctuating temperatures, and high organic load in the system.

Preventive and Operational Measures

Integrated prevention is key to reducing fungal outbreaks in Indian RAS. Recommended measures include:

- **Maintain Optimal Water Quality**
- **Reduce Fish Stress**
- **Egg Disinfection**
- **Biosecurity**

Indian aquatic health guidelines emphasize cautious use of chemical treatments in RAS, considering the closed system's biofilter sensitivity and environmental discharge risks. Thus, treatment choice and dosing must balance efficacy, fish safety, and environmental sustainability.

Parasitic Diseases: Identification and Treatment in RAS

Common Parasitic Diseases in Recirculating Aquaculture Systems (RAS)

Two major parasitic diseases frequently encountered in Indian RAS setups are **Ichthyophthiriasis** (commonly known as Ich) caused by *Ichthyophthirius multifiliis*, and **Trichodiniasis** caused by ciliates belonging to the genus *Trichodina*. Both diseases severely impact fish health and productivity if not promptly identified and treated.

Clinical Signs and Diagnosis

- **Ichthyophthiriasis (Ich):** Characterized by numerous small, white, salt-like spots distributed over the skin, fins, and gills. Affected fish exhibit flashing, increased

respiratory effort, lethargy, and reduced feeding. The parasite invades epithelial tissues forming cysts, causing tissue damage.

- **Trichodiniasis:** Presents as excessive mucus production, skin sloughing, and sometimes erythema. Fish may scrape against surfaces and show rapid opercular movement due to irritation caused by *Trichodina* spp. infestation on skin and gills.

Operational and Management Measures

- **Reduce Fish Stocking Density**
- **Improve Filtration and Biofiltration**
- **Regular Monitoring**
- **Quarantine of New Stocks**
- **Water Quality Management**.

Environmental and Nutritional Diseases: Causes and Management

Gas Bubble Disease

Gas Bubble Disease (GBD) arises from supersaturation of gases (mainly nitrogen or oxygen) in RAS water, causing gas embolisms in fish tissues. Symptoms include erratic swimming, gas bubbles visible under the skin, hemorrhages, and buoyancy problems. Diagnosis relies on observing physical signs and measuring dissolved gas levels above 110% saturation.

Operational strategies: Regular monitoring of dissolved gases and maintaining dissolved oxygen below saturation limits are critical. System design improvements to ensure efficient gas exchange and avoid sudden pressure changes help prevent GBD outbreaks in Indian RAS facilities.

Nutritional Deficiencies

Nutritional diseases stem from imbalanced or inadequate feed composition, leading to deficiencies in essential vitamins, minerals, or amino acids. Common signs include stunted growth, poor coloration, skeletal deformities, hemorrhages, and increased susceptibility to infections.

Management: Diagnosis is based on clinical signs, feed analysis, and growth performance evaluation. Treatment involves correcting feeding regimes by providing balanced, species-specific formulated diets rich in micronutrients. Supplementation with vitamins such as C and E is often beneficial.

Preventive measures: Routine assessment of feed quality and formulation adjustments aligned

with fish developmental stages are vital. Incorporating feed additives and maintaining stable water quality supports nutrient uptake and overall fish health in Indian RAS contexts.

Best Practices and Operational Strategies for Disease Prevention in Indian RAS

Effective disease prevention in Recirculating Aquaculture Systems (RAS) requires an integrated approach combining chemical treatments with strong operational practices tailored to Indian conditions. Central to this is **good husbandry**, which includes:

Key Treatment Methods for Disease Management in RAS

Effective disease management in Recirculating Aquaculture Systems (RAS) necessitates a comprehensive approach that integrates multiple treatment methods adapted to the Indian aquaculture context. The densely stocked and water-reused environment of RAS poses unique health challenges that can be mitigated through targeted interventions, encompassing prophylactic measures, water quality management, microbial control, vaccine application, diagnostics, and sound husbandry practices. This section reviews each of these treatment modalities in detail.

Prophylactic Measures: Reducing Stress Through Husbandry and System Management

Prophylaxis is the first line of defense in disease control and primarily focuses on minimizing stressors that predispose cultured species to infections. In India's tropical climate, managing environmental factors such as temperature fluctuations, dissolved oxygen levels, and stocking densities is critical.

These measures, supported by guidelines from ICAR-CIFA, form the cornerstone for sustainable health management by maintaining fish welfare and resilience to disease (ICAR-NCAAH)-2.

Water Quality Management: Filtration Systems and Disinfection

Maintaining optimal water quality is critical for controlling pathogen loads and supporting fish health in RAS..

- **Mechanical Filtration**
- **Biological Filtration**
- **Chemical Filtration and Treatment**

Routine cleaning schedules, monitoring of filtration efficacy, and controlled flushing procedures are vital to prevent system breakdown and maintain water quality standards essential in tropical Indian conditions (ScienceDirect, 2023)-3.

Water Sterilization Techniques: UV Sterilization and Ozonation

To further reduce pathogen load beyond conventional filtration, water sterilization is commonly employed in Indian RAS.

- **Ultraviolet (UV) Sterilization**
- **Ozonation**

Both UV and ozone treatments are applied selectively based on system needs and water source characteristics, offering reliable pathogen control without chemical residues (Extension MS State, 2024)-4.

Probiotics and Bioremediation: Balancing Microbial Flora

Indian aquaculture research emphasizes the strategic use of probiotics and bioremediation agents to establish a healthy microbial community within RAS. These beneficial bacteria and enzymes contribute to:

- Outcompeting pathogenic microorganisms through competitive exclusion.
- Enhancing water quality by degrading organic waste and toxic by-products.
- Stimulating the immune system of cultured species, improving disease resistance.(ICAR-NCAAH)-5.

Vaccine Development Efforts by Indian Institutions

Vaccination represents a sustainable prophylactic strategy to control specific infectious diseases in RAS. Indian institutes such as ICAR-CIFA and ICAR-CIBA have made considerable progress in developing vaccines for prevalent pathogens including:

- Viruses causing fish mortalities, like the Cyprinid herpesvirus.
- Bacterial pathogens such as *Aeromonas hydrophila* and *Edwardsiella tarda*.
- Parasites that affect growth and survival rates.

These vaccines, delivered through injection, oral routes, or immersion baths, are subject to continual refinement to increase efficacy and cost-effectiveness under Indian RAS conditions (Down To Earth, 2024)-6.

Advanced Diagnostics for Early Pathogen Detection

Early and accurate detection of pathogens enables prompt intervention, limiting disease spread in tightly controlled RAS environments. Advanced diagnostic tools are increasingly accessible to Indian aquaculture facilities, including:

- Molecular techniques such as PCR (polymerase chain reaction) for identifying viral and bacterial DNA/RNA.
- Immunological assays like ELISA for detecting specific pathogen antigens or antibodies.
- Rapid on-site test kits and biosensors for routine surveillance.
- Microscopic examination supported by staining techniques to identify parasitic infections.

Indian research centers conduct training and provide extension services to enhance the adoption of these diagnostic methods, which significantly improve health monitoring and decision-making in RAS operations (Extension MS State, 2024)-7.

Biosecurity Strategies for Minimizing Disease Risks in RAS

Effective biosecurity is fundamental to preventing the introduction and spread of diseases within Recirculating Aquaculture Systems (RAS) in India. Given the high-density culture environments and system recirculation, pathogens can rapidly propagate if stringent biosecurity measures are not implemented. This section outlines comprehensive biosecurity strategies tailored for RAS operations in India, addressing system design, operational controls, personnel protocols, and contingency planning.

System Design Considerations for Biosecurity

Designing RAS facilities with biosecurity in mind is the crucial first step towards minimizing disease risks. Indian RAS infrastructure should integrate features that:

- **Facilitate thorough cleaning and disinfection**.
- **Enable effective isolation**
- **Support controlled water flow**.
- **Incorporate appropriate drainage**

Collaborations with Indian research bodies such as ICAR-CIFA have highlighted the importance of these design elements to enhance biosecurity without compromising operational efficiency (ICAR-NCAAH)-8.

Isolation and Separation Tactics

Physical separation of fish stocks based on age, species, and health status is vital to limit pathogen transmission:

- **Quarantine Protocols:** Newly introduced fish must undergo a quarantine period of at least 14 days in dedicated isolation tanks where health status is closely monitored before integrating them into the main system.
- **Segregation of Sick Fish:** Prompt segregation or removal of any clinically ill fish helps reduce infection pressure in healthy stocks.
- **Separate Equipment Use:** Employing dedicated nets, hoses, and tools for different tanks avoids mechanical transfer of pathogens.

Implementing such strategies reduces opportunities for cross-infection, a precaution strongly recommended by Indian aquaculture experts (Down To Earth, 2024)-9.

Access Control and Foot Traffic Management

Human movement within and between production units is a recognized vector for pathogen spread. Therefore, controlling access and foot traffic is imperative:

- **Restricted Entry**
- **Disinfection Stations**
- **Personal Hygiene**
- **Visitor Management**

These measures, when consistently enforced, significantly contribute to maintaining a contamination-free environment.

Equipment Cleaning and Disinfection Protocols

Equipment is a potential fomites source that can aid disease transmission if not properly managed. Indian RAS operations emphasize:

- **Regular Cleaning**
- **Disinfection**
- **Dedicated Equipment**
- **Storage Practices**

Adherence to these protocols is critical as stressed by health management guidelines issued by national aquatic animal health organizations (ICAR-NCAAH)-10.

Source Management: Procuring Healthy Stock

Prevention starts at the source. Procuring fish stock from reputable hatcheries with certified health status reduces the risk of introducing diseases into the RAS:

- **Health Certification**

- **Supplier Audits**
- **Vendor Relationships**Indian government programs promote quality assurance frameworks for hatcheries to support biosecure sourcing strategies (Down To Earth, 2024)-11.

Water Source Protection and Disinfection

Water is a primary medium for pathogen entry in RAS. Biosecurity strategies must include:

- **Baseline Water Quality Monitoring**
- **Physical Protection**
- **Water Treatment**

These approaches help maintain pathogen-free water inputs, a key factor in minimizing disease outbreaks (Extension MS State, 2024)-12.

Waste Disposal and Management

Accumulated waste and dead fish are significant pathogen reservoirs that can fuel disease outbreaks if not managed properly:

- **Immediate Removal**
- **Safe Disposal**
- **Sludge Management**

National aquaculture health management guidelines stress the importance of effective waste handling in RAS biosecurity (ICAR-NCAAH)-13.

Personnel Training and Biosecurity Enforcement

The most advanced biosecurity measures fail without trained and conscientious personnel. Training programs should cover:

- **Understanding Disease Transmission**
- **Implementing Protocols**
- **Routine Monitoring**
- **Continuous Improvement**

Training initiatives led by Indian research centers and government agencies aim to bridge knowledge gaps among aquaculture workers (ICAR-NCAAH)-14.

Health Monitoring, Surveillance, and Contingency Planning

Ongoing health monitoring and readiness for outbreak management are critical:

- **Routine Health Checks**

- **Diagnostic Sampling**
- **Record Keeping**
- **Contingency Plans**

Indian research institutions advocate integrating surveillance data with rapid response strategies to mitigate disease impact efficiently (Down To Earth, 2024)-15.

Challenges and Future Directions in Disease Management for RAS in India

Indian RAS operations face challenges including high costs, limited technical capacity, and knowledge gaps in disease epidemiology and management. Current research at institutions like ICAR-CIFA focuses on pathogen-host interactions and developing rapid diagnostic tools, alongside innovative approaches such as probiotics, bioremediation, and vaccine advancements. Future directions emphasize integrating smart monitoring technologies, enhancing farmer training on biosecurity, and adopting cost-effective, sustainable treatment protocols.

Sources: ICAR-NCAAH, Down To Earth, 2024-16

Diseases diagnosis

The latest disease diagnosis guidelines can be categorized into three levels of infection identification:

Level I: This encompasses farm/production site observations, record-keeping, and health management. This contextual information significantly aids in confirming the diagnosis of infections through level II and level III diagnostics.

Level II: This involves specialized techniques such as histopathology, which are typically not feasible to perform directly at the farm site.

Level III: Encompasses advanced techniques that demand a high level of infrastructure investment, trained personnel, and substantial expenditure for conducting the tests.

Table 1: External signs observed during level I diseases diagnosis

Clinical signs	**Types of diseases**
Gills with excess mucus	Bacterial, parasitic, environmental or nutritional
Gills necrotic	Bacterial, parasitic, fungal
Gills pale	Viral, bacterial, nutritional
Skin with excess mucus	Parasitic, environmental
Re-pigmented areas in skin	Bacterial or parasitic

Dark skin pigmentation	Viral, bacterial, nutritional, eye parasite
Haemorrhage, erythemia	viral, bacterial, parasitic
Frayed, eroded, erythemia in fins	Bacterial, parasite, mechanical, physiological disorder
Exophthalmia, haemorrhaged opaque eyes	Viral, bacterial, parasitic, gas super saturation
Ulceration, necrotisation	Bacterial, parasitic
Dropsy	Bacterial, viral, metazoan parasite
Enlarged abdomen (fluid accumulation)	Viral, bacterial, parasitic
Growth, nodules, raised spot on skin	Viral, parasitic, neoplasmic, fungal

.

Table 3: Common fish diseases in India their symptoms and treatment

Bacterial Diseases				
Disease Name	**Causative Agent**	**Clinical Symptoms**	**Treatment**	**References**
Furunculosis	*Aeromonas salmonicida*	Appearance of boillike lesions, stomach filled with mucus, blood and sloughed epithelial cells, and fusion of gill lamellae	Oxytetracycline 50-75 mg/kg fish weight/day for 10 days Sulfamerazine 150-220 mg/kg fish weight/day for 10-14 days	Ravi and Jithender, 2007 [17]
Dropsy	*Pseudomonas punctata*	Bloating of the body, accumulation of yellow colored fluid inside the body cavity	5 ppm potassium permanganate for 2 minutes dip bath 250 mg oxytetracycline in 20 l water for 2 to 3 days	Vajargah, 2022; Ravi and jithender, 2007 [20, 17]
Fin and tail rot	*A. hydrophila, Pseudomonas* spp	Erosions, discoloration and disintegration of fins and tails	Tetracycline 3-4 gm/100 l for 2-3 days 1 minute dip treatment in 500ppm copper	Mishra *et al*., 2017; Ravi and jithender, 2007 [18, 17]

			sulphate solution	
Columnaris	*Flexibacter columnaris* or *Cytophaga columnaris*	whitish or greyish plaques are seen over head and back giving a saddle back like appearance	Oxytetracycline 220 mg/kg/day for 10 days Potassium permanganate 500mg/100l for 1 hour Malachite green 10mg/100l for 30- 96 hours copper sulfate bath at 37 mg/L for 20 min copper sulfate to pond water at 0.5 mg/L	Davis, 1992 Mishra *et al*., 2017; Ravi and jithender, 2007 [19, 18, 17]
Motile aeromonas septicaemia	*Aeromonas hydrophila*	Haemorrhagic and ulcerative lesions on skin fins, head, exophthalmia	Oxytetracycline 50 to 75 mg/Kg of fish per day for 10 days Trimethoprim-sulphamethoxazole at 10 g/t of pool water for 3 days Ciprofloxacin at 5 ppm for 5 days potassium permanganate at 2 to 4 mg/L	Cipriano *et al*. 1984, Adanir and Turutoglu, 2007, Chirila *et al*. 2008 [21, 22, 5]
Eye disease	*Aeromonas liquifaciens*	Cataract of eyes, affect cornea,	Chloromycetin 8-10 mg/liter bath	Mishra *et al*., 2017 [18]
		eyeball gets putrefied	for 1 hour for 2-3 day	
Vibriosis	*Vibrio parahemolyticus, Vibrio salmonicida* and *Vibrio harveyi*	Red spots on the ventral and lateral area of fish, swollen and dark skin lesions that ulcerate	Sulfamethazine 2 gm/100 pounds of fish / day Terramycin3 - 4 gm/100 pounds of fish/day for 10 days	Mishra *et al*., 2017; Ravi and jithender [18, 17]

Fungal disease				
Saproligniasis	*Saprolegnia parasitica*	Appearance of fluffy tufts of cotton- like material, haemorrhage, exposure of jaw bones, blindness and inflammation of liver and intestine	1-3 ppm malachite green for one hour 1:500 formalin for 15 minutes 3 to 5 mg/1 methylene blue as a preventative measure after the eggs are laid NaCl 5-10 ppt H_2O_2 500 ppm for 15 minutes	Lipton, 2006; Ravi and jithender, 2007 [23, 17]
Branchiomycosis	*Branchiomyces sanguinis* and *Branchiomyces demigrans*	Respiratory distress, fungus develops on or in gill tissue, or penetrates the blood vessels causing obstruction, congestion and necrosis or gill tissues.	0.3 ppm Malachite green for 24h Dip in 3-5% NaCl for 5 to 10 min. 0.05 g/kg grisin mini antibiotic feed for 3 days 5 ppm potassium permanganate bath for 5 to 10 minutes	Abduhalilova *et al*., 2023; Ravi and jithender, 2007 [25, 17]
Epizootic ulcerative syndrome	*Aphanomyces invadans*	Red spot, blackish burn like mark or deeper ulcer with red centres and white rims	Calcium hydroxide at 375kg/Ha NaCl is applied at 1250-1875 kg/ha CIFAX at 1 liter/ha Bleaching powder at 5- 10 kg/ ha Oxytetracycline at 60-100 mg/ kg with feed for 7 days	Manna at al., 2023; Ravi and jithender, 2007 [26, 17]
Parasitic diseases				
White spot disease	*Ichthyophthirius multifilis*	characterised by the presence of small white spots on the skin or gills	1.5 to 2.5% of Sodium chloride for 10 to 30 minutes/ 7 days Potassium permangan	Lipton, 2006; Ravi and jithender, 2007;

			ate at 2 to 5 ppm Malachite green at 0.1 ppm for 3 to 4 days	Mishra *et al*., 2017 [23, 17, 18]
Whirling disease	*Myxobolus cerebralis*	characterized by whirling movement of the affected fish, malformations of the skeleton & black coloration of the posterior part of the body	There is no treatment of this disease if fishes are infected it should be destroyed by applying quicklime at the rate of 2t/ha	Ravi and jithender, 2007; Mishra *et al*., 2017 [17, 18]
Costiasis	*Ichthyoboda necator*	Characterized by bullness of the skin, and respiratory manifestation	Formalin bath for 1 hour at 250mg/l sodium chloride for 20 to 30 min at 10-20gm/l Acriflavine bath for 10 hours for 10 mg/l 5mg/l potassium permanganate	Ravi and jithender, 2007; Mishra *et al*., 2017 [17, 18]
Hole in head disease	*Hexamita. salmonis, H. truttae* and *H. intestinalis*	Characterized by anorexia, emaciation and abdominal distension	Metronidazole 5mg/1 liter for 3 hours, Magnesium sulfate 0.2-0.3% of the diet for 3 days	Buchmann, 2022; Ravi and jithender, 2007; Mishra *et al*., 2017 [24, 17, 18]
Dactylogyrosis	*Dactylogyrus sp*	Mostly affects gills, destroying the gill filaments, gills with clumps of white masses. Parasites can be observed under microscope in sample from gills	10 ppm potassium permanganate bath for 1-2 hour sodium chloride 2.5% for 1 hour by bath Mebendazole 1mg/liter for 24 hours by bath method	Buchmann, 2022; Ravi and jithender, 2007; Mishra *et al*., 2017 [24, 17, 18]

Gyrodactylosis	*Gyrodoactylus sp.*	These parasites which grow on and destroy the skin, gills with clumps of white masses, frequently associated with secondary infections.	10 ppm potassium permanganate bath for 1-2 hour sodium chloride 2.5% for 1 hour by bath Mebendazole 1mg/liter for 24 hours by bath method	Buchmann, 2022; Ravi and jithender, 2007; Mishra *et al*., 2017 [24, 17, 18]
Argulosis	*Argulus*	Loss of scales and presence of red spots, damage of gills	500 ppm of ammonium chloride 0.25 ppm of dylox, Ivermectin 50g/kg of body weight	Buchmann, 2022; Ravi and jithender, 2007; Mishra *et al*., 2017 [24, 17, 18]
Lernaeasis	*L. chackoensis*	Body unsegmented with its anterior part deeply embedded in host tissue with the help of a hold fast organ, infect nostril, skin, fin, and gills	250 ppm formalin for 30 to 60 minutes. 0.2 ppm gammexane for 72 hours, 2 ppm of lexone potassium permanganate at 5mg/L	Buchmann, 2022; Ravi and jithender, 2007; Mishra *et al*., 2017 [24, 17, 18]
Viral diseases				
Spring viraemia of carp	Spring viraemia of carp virus	Exophthalmia, pale gills, haemorrhages on the skin, base of the fins and the vent, and abdominal distension or dropsy	No treatment is available	Mishra *et al*., 2017; Ravi and jithender, 2007; Lipton, 2006 [18, 17, 23]
Infectious haematopoietic necrosis	Infectious haematopoietic necrosis virus	Darkening of the skin, pale gills, ascites, distended abdomen, exophthalmia, and	No treatment is available	Mishra et al., 2017; Ravi and jithender,

		petechial haemorrhages internally and externally		2007; Lipton, 2006 [18, 17, 23]
Carp edema virus disease	Carp edema virus	Swollen gills or gill necrosis, enophthalmos, skin lesions at the base of the fins or around the mouth and inflammation of the anus	No treatment is available	Mishra et al., 2017; Ravi and jithender, 2007; Lipton, 2006 [18, 15, 23]
Lymphocystis	lymphocystivirus	Small moderate wart-like nodules over the external body surfaces like fins, skin or gill and pop eye.	No treatment is available	Mishra et al., 2017; Ravi and jithender, 2007; Lipton, 2006 [18, 17, 23]
Koi herpesvirus disease	Koi herpesvirus	Loss of epidermis, irregular patches of pale colouration or reddening, excessive or reduced mucous secretion and sand paper like skin texture	No treatment is available	Mishra et al., 2017; Ravi and jithender, 2007; Lipton, 2006 [18, 17, 23]
Viral nervous necrosis	Nervous necrosis virus	Erratic swimming behavior including spiral, whirling or belly-up swimming with inflation of swim bladder	No treatment is available	Mishra et al., 2017; Ravi and jithender, 2007; Lipton, 2006 [18, 17, 23]

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RECENT TRENDS IN AQUACULTURE RECIRCULATORY AQUACULTURE SYSTEM (RAS)- NFDB

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HARNESSING ION UPTAKE KINETICS TO ENHANCE NUTRIENT UPTAKE EFFICIENCY IN SUGARCANE

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Introduction

Plants require major nutrients nitrogen (N), phosphorus (P), and potassium (K) along with secondary and micronutrients for optimum growth and development. Nutrients are absorbed from the soil through plant roots in the form of ions dissolved in soil solution. The rate at which nutrient ions are taken up by plants is known as *ion uptake kinetics*. The rate of nutrient uptake is influenced by various internal and external factors not limited to soil properties, root system traits, and nutrient availability. Understanding nutrient uptake kinetics is important because it helps to optimize nutrient use, optimize plant developmental processes and increase crop yield. Optimum nutrient application plays a crucial role in sustainable agriculture by reducing excessive fertilizer use and minimizing the deleterious environmental impact. This article provides an overview of nutrient uptake, factors influencing it, variability existing for ion uptake kinetic traits in crop plants with a potential application to enhance nutrient uptake efficiency in sugarcane.

Factors Affecting Nutrient Uptake

The rate at which plants absorb nutrients from the soil is influenced by several external and internal factors. These factors can either enhance or limit the nutrient uptake process.

Understanding the factors influencing nutrient uptake are important for managing plant nutrition and improving fertilizer use under different soil and climatic conditions.

External Factors

Soil pH: Soil pH affects solubility and availability of nutrients, for e.g. *P* becomes less available in acidic soils (pH<5.5) affecting crops like **maize** in red lateritic soils (Fageria and Moreira, 2011).

Soil moisture: Water dissolves nutrients and transports them to roots, hence soil moisture content is a crucial factor that determines the rate of ion uptake. In dry paddy fields, **plants** suffered **K deficiency** due to poor mobility of ions in the absence of water (Pathak and Aggarwal, 2012).

Temperature: Low temperature slows down root metabolism and enzyme function, in turn reducing ion uptake. In cold winter days, **wheat** plants were reported to absorb less **nitrate** ions due to reduced root activity (Taiz et al., 2015).

Nutrient concentration: High nutrient availability in the soil solution increases uptake, but this relationship is not always proportional as excess uptake can cause toxicity symptoms in plants. Excess N availability boosts **lettuce** growth but may lead to **tip burn** due to calcium imbalance (**Marschner**, 2012).

Oxygen availability: Roots need oxygen for respiration and active nutrient ion transport, hence are essential to sustain nutrient uptake. In **flooded soybean fields**, oxygen deficiency reduced uptake of N, K, calcium, and magnesium (Sathi et al., 2022).

Table 1. Ideal range of external factors affecting nutrient uptake

Factors	**Ideal range for optimum nutrient uptake**
Soil pH	6.0 to 7.5
Soil moisture	Field capacity (40 to 80%)
Soil temperature	20 °C to 35 °C
Soil oxygen diffusion rate	$> 20 \times 10^{-8}$ g O_2 cm^{-2} min^{-1}
Available nutrient level in soil solution (0-20 cm)	NO_3-N: 3100 µM, NH_4-N: 48 µM, PO_4-P: 1.5 µM, K: 510 µM, Ca: 1650 µM, Mg: 490 µM, SO_4-S: 590 µM, Zn: 0.48 µM
Critical soil nutrient level	P: 4.9 to 58 mg kg^{-1}, K: 28 to 284 mg kg^{-1}, Zn: 1.8-13 mg kg^{-1}, Fe: 4.7 to 8.5 mg kg^{-1}

Source: **Marschner**, 2012; Neira et al., 2015; Siatwiinda et al., 2024

Internal Factors

Genotype: Different crop species or varieties have varying nutrient uptake capacities. In zinc-deficient soils, traditional r**ice variety** Jalmagna absorbed **zinc** more efficiently compared to IR74 (Wissuwa et al., 2006).

Root system traits: Deep, wide, and branched roots explore more soil volume, and can therefore intercept and take up nutrient ions at a faster rate. **Sorghum** plants with deeper roots absorbs more **P** compared to shallow-rooted crops like **onions** (Fageria and Moreira, 2011).

Plant age and growth stage: Young and actively growing plants have higher and varied nutrient demands, hence take up more nutrients as compared to old and senescing plants based on their requirement. **Young tomato seedlings** need more **N** and **calcium** during early growth, while **fruiting plants** require more **K (Marschner**, 2012**)**.

Nutrient Transport Mechanisms

Plants absorb major nutrients from the soil in the ionic forms such as nitrate (NO_3^-), ammonium (NH_4^+), phosphate (PO_4^{3-}), and potassium (K^+). These nutrient ions are transported from the soil solution into the into root cells through two major transport mechanisms:

Passive Transport

Involves the movement of nutrient ions along a concentration gradient, from high to low concentration, and does not require energy. It includes both simple diffusion and facilitated diffusion through protein channels.

Active Transport

Allows the plants to absorb nutrient ions against the concentration gradient, from low to high concentration, which requires energy in the form of ATP. This process relies on specialized membrane-bound transporter proteins such as nitrate transporters (NRTs), ammonium transporters (AMTs), phosphate transporters (PHTs), and proton pumps like H^+-ATPases helps to maintain the electrochemical gradient necessary for nutrient uptake. Active transport is especially important in soils with low nutrient availability, ensuring that plants can still meet their nutritional demands. Root hairs play a significant role in increasing the surface area for nutrient absorption. The root system traits such as architecture, root length, branching and depth affects how efficiently a plant can take up nutrients. Some plants like maize form symbiotic relationship with mycorrhizal fungi, which helps in absorbing nutrients like P more effectively (Smith and Smith, 2011).

Uptake of nutrient ions depend on the expression and function of transporter proteins, which are primarily localised to the root tissues, and may exhibit low or high affinity between the ion and transporter. Different transporter gene families have been discovered for several nutrients including but not limited to N, P, and K. Molecular characterisation of genotypes with contrasting nutrient use efficiency is limited in sugarcane as compared to other graminaceous crops like maize, rice, and wheat (Sathee et al., 2022). *In silico* analysis of the polyploid sugarcane genome (Healey et al., 2024) revealed the presence of nitrate transporter NRT1/PTR and N assimilatory enzyme NR, phosphate transporters PHT1-1, PHT 1-2, PHT1-3, PHO1-1, PHO1-2, PHO1-3, H^+-Pi cotransporter and H^+-ATPase symporter, and potassium channels AKT1, AKT2, AKT3, HAK1 and HAK5. Further, functional elucidation of high affinity nutrient transporters in sugarcane such as ScNRT2.3 (Hui et al., 2024), EaPHT1;2 (Murugan et al., 2023), and ScHAK10 (Luo et al., 2022) with proven role in enhancing the uptake of N, P and K, respectively, may be potential targets to develop nutrient uptake efficient sugarcane varieties.

Concept of Ion Uptake Kinetics

Ion uptake kinetics refers to the rate at which plants absorb nutrient ions from the soil, as this rate is not constant. It varies depending on the type of nutrient, plant species, environmental condition, and the availability of nutrients in the soil solution and/or rhizosphere. To study this process, different kinetic models are used, among which the Michaelis-Menten model is the most widely adopted (Epstein and Hagen, 1952). Originally developed for enzyme activity, the Michaelis-Menten model describes how effectively nutrient uptake rate increases with nutrient ion concentration in soil. Traits governing nutrient uptake efficiency include root morphology, exudates, and expression of ion transporters, which determine kinetic parameters (I_{max}: maximal uptake rate, C_{min}: minimum ion concentration at which net influx occurs, K_m: affinity between transporter and nutrient ion). Ion uptake kinetic traits could be used to select genotypes for better nutrient uptake efficiency, wherein plants with high I_{max} are suited to high input agricultural systems, plants with low K_m and low C_{min} could yield better with low inputs.

Three important traits of ion uptake kinetics are:

I_{max}: Represents the highest possible rate at which a plant can absorb a nutrient when the nutrient is available in large amounts.

K_m: Represents the concentration of nutrient ion at which the uptake rate is half of I_{max}. A lower K_m means the plant has a high affinity for that nutrient and can absorb it efficiently even when the ion is in a low supply.

C_{min}: The lowest external concentration at which nutrient uptake begins. Below this, the plant cannot absorb the nutrient effectively. It is also called the threshold concentration.

These traits are used to compare how different plants or varieties absorb nutrients and determine which ones are more efficient. This knowledge can be used to select or breed plants that perform better in low-fertility soils or under nutrient stress conditions.

Crops with Superior Ion Uptake Kinetics Exhibit Enhanced Nutrient Efficiency

Studies revealed that nutrient uptake rate varied significantly between plant genotype and environmental condition. Uptake rate of N in maize root segments varied considerably based on the distance from the root tip (Rao et al., 1997). Abiotic stresses such as salinity results in nutrient imbalance due to sodium and chloride ions competing with essential nutrients N, K, and calcium, while drought affects uptake and translocation of nutrients (Hu and Schmidhalter, 2005). Amongst cereal crops, I_{max} was highest in rye, while C_{min} and K_m were lower as compared to wheat and triticale (Pandey et al., 2006). Higher supply of carbon dioxide to wheat seedlings reduced the uptake of nitrate ions, revealing differential genotypic behaviour and nitrate dose-dependence (Adavi et al., 2021). Although ion uptake kinetic studies in sugarcane are limited as compared to other crops, N use efficient varieties had lower I_{max} and K_m than inefficient ones (Hajari et al., 2014). Such reports substantiate the need to identify nutrient uptake efficient genotypes in sugarcane to facilitate better fertilizer scheduling under different soil conditions. Ion uptake kinetics has vital practical uses in sugarcane agriculture to help growers to manage nutrients more efficiently leading to better crop growth and reduced environmental damage.

Improved crop varieties: Crops with high nutrient uptake efficiency (high I_{max}, low K_m) perform better in resource poor soils (Siddiqi and Glass, 1981). They absorb nutrients more quickly and effectively even at low concentrations. These traits can be selected through trait-specific breeding programmes. Rice genotypes such as **WAB181-18** and **Nerica6** (Rose et al., 2010), Kasalath, Nerica10, IAC47 and Dular (Rose et al., 2013) were efficient in P uptake, which was attributed to better ion uptake kinetic traits in few but not all tested genotypes.

Efficient fertilizer use: Understanding nutrient uptake pattern helps apply fertilizers more precisely. Applying the right dose at the right time improves efficiency. This reduces fertilizer

waste and lowers cultivation costs. It also minimizes environmental pollution. Practices such as split N application and fertigation may be scheduled based on ion uptake traits.

Conclusion

Ion uptake kinetics is an important area of plant science research that helps us to understand how plants efficiently absorb essential nutrients from soil solution. Nutrient uptake is governed by several intrinsic and extrinsic factors including the plant's genetic makeup, root system traits, soil properties, nutrient type and environmental conditions such as pH and moisture. By utilising the knowledge on traits such as I_{max}, K_m and C_{min}, we can compare the nutrient absorption capacities of different species of *Saccharum*, allied genera, and cultivated sugarcane genotypes, which in turn aid in identifying nutrient uptake efficient varieties. The practical application of this knowledge is significant for developing sustainable cultivation practices for sugarcane. Understanding ion uptake kinetic traits contributes to improved crop yield while minimizing environmental pollution. Furthermore, it supports development of crop varieties with enhanced nutrient uptake efficiency and capable of thriving under resource poor soil conditions. To conclude, a better understanding of nutrient uptake processes leads to smarter farming practices with significant improvement in crop productivity.

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NANOTECHNOLOGICAL APPROACHES FOR CLIMATE RESILIENT AGRICULTURE

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Introduction

Smart delivery systems based on nanotechnology control the release of pesticides, reducing toxicity and enhancing environmentally friendly farming. By combining genetic modifications and nano-bioengineering, nanotechnology is expected to contribute to the development of climate-resilient crops. The application of carbon-based nanomaterials, such as carbon nanotubes and graphene oxide, can improve plant growth, stress tolerance, and seed germination. Future advancements in nano-enabled agriculture are expected to focus on three key areas: biodegradable and environmentally friendly nanomaterials, precision nanotechnology for smart farming, and the integration of artificial intelligence (AI) and the Internet of Things (IoT) with nanosensors for automation and real-time monitoring.Additionally, it can be used to enhance food processing, create new food products with more flavours and tastes, boost food goods' shelf life, and provide nanotechnology-based tools for spotting and stopping food spoiling.

Smart Practices and Technologies

In 2011, ICAR initiated a multi-institutional, multi-disciplinary network project called the National Initiative on Climate Resilient Agriculture (NICRA). Through strategic research and technology demonstrations, the project seeks to increase Indian agriculture's resilience to climate change and variability. A fantastic opportunity to collaborate with farmers to address present climatic variability with corresponding responses is provided by NICRA's Technology Demonstration Component (TDC). One hundred of the most vulnerable districts are implementing participatory on-farm demonstrations of various technology. Drought, floods,

cyclones, heat waves, cold waves, and other climate vulnerabilities are addressed.The secret to sustainability in agriculture, particularly in light of climate risk, is to increase resilience. As a result, the emphasis is on climate variability adaptation, which includes suitable reactions to unforeseen circumstances. In highly intensive industrial systems when natural resources are degrading, sustainability is the urgent objective. Therefore, in order to maintain the productivity gains previously made, the primary focus of technological demonstrations in these areas is not on increasing productivity but rather on interventions linked to coping with vulnerability and improving the efficiency of natural resource usage.

Developing climate-resilient crops

- A species-by-species and region-by-region study of anticipated environmental problems is necessary to meet genetic mitigation demands. Breeders, farmers, and climate change scientists may work closely together to achieve this. Despite the fact that adaptation is very site specific, there may be groups of locations worldwide that deal with comparable adaptation challenges or where the current environment may be a projection of the future environment for certain other places. These sites can be widely used to screen for available germplasm resources and to grow crops naturally and consistently, creating crop populations that serve as germplasm conduits for international plant breeding initiatives.
- Climate-resilient crop varieties and cropping systems targeted at various breeding aims may be developed more quickly with the use of participatory breeding and varietal selection. Consolidation of knowledge regarding CO2 assimilation, nutritional dynamics, mixed cropping, vectors, pests, diseases, intercropping, water consumption, temperature responses, gene pools, and genomic resources in plants may further enhance such efforts. To incorporate the entire adaptation process—from bio-reserves to genes to cultivars—breeding must integrate conservation genetics and genomics.

Nano biosensor

- The use of nano-biosensors in precision agriculture has completely changed how farmers track crop health, nutrient levels, and soil quality in real time. Utilising nanomaterials like carbon nanotubes, graphene, and quantum dots, these sophisticated sensors accurately

detect and measure key soil factors like moisture content, pH, and levels of nitrogen, phosphorus, and potassium (NPK).

- Recent developments in artificial intelligence (AI) and Internet of Things (IoT)-enabled smart nano-sensors have improved precision agriculture even further by facilitating automated decision-making, remote monitoring, and real-time data collection. In the end, wireless nano-sensor networks improve resource efficiency and farm output by enabling farmers to minimise crop losses from pests and diseases, optimise irrigation, and cut down on fertiliser waste.

Carbon nanotubes used for soil remediation

Heavy metal and chemical pollution in soil constitute a serious issue for sustainable agriculture. Carbon nanotubes (CNTs) are a viable nanotechnology option for soil remediation due to their high adsorption capacity, chemical stability, and surface reactivity (Mohan et al., 2019). CNTs effectively bind and immobilise hazardous elements such as lead (Pb) and cadmium, arsenic (As), lowering their bioavailability and inhibiting crop absorption.

Nanotechnology of abiotic stress management

- Abiotic stressors primarily affect photosynthesis by degrading chlorophyll and disrupting chloroplast ultrastructures. The NPs improve antioxidant safety and osmoregulation, mitigating adverse effects. Nanoparticles mimic antioxidants and maintain redox potential in response to abiotic stressors. These nanoparticles enhance photosynthetic efficacy by boosting chlorophyll and light absorption.
- The effects of the colloidal Zn and Cu nanoparticle solution resulted in a fluctuating ratio of chlorophyll content (Chl a/Chl b) in the leaves. Additionally, an increase in carotenoid levels in the leaves showed how the plant had adapted to drought conditions.
- Unwanted microbes are eliminated by silver in agricultural soils and hydroponic systems. As a foliar spray, it is also used to combat fungus, mould rot, and numerous other plant diseases. Silver also contains silicate, silver salt, and water-soluble polymers that react to radioactive rays, making it a significant growth stimulant for plants. In order to mitigate the detrimental effects of salinity on fenugreek germination and growth, an experiment was carried out using silver nanoparticles. Application of AgNPs was found to be generally helpful in increasing the salinity tolerance of fenugreek seedlings, and it was proposed that applying nanoparticles may trigger several plant defence systems against salt stress.

- Additionally, research is being done to determine whether selenium nanoparticles (Se-NPs) have the ability to lessen the harmful effects of high temperatures (HT) on plants. However, not enough is known about the application of selenium nanoparticles (Se-NPs) to agricultural crops to reduce the effects of high temperatures.
- High carbon dioxide levels reduce photosynthesis in many plants. Previous study indicates that abrupt increases in carbon dioxide can harm several plant types. Carbon dioxide levels can reduce the nutritional value of basic crops, such as wheat. Concerns have been raised about the hazards of nanomaterials, as they may be released into the environment and harm species. Concerns have been raised about the hazards of nanomaterials, as they may be released into the environment and harm species.
- Carbon dioxide (CO2) is one of the primary greenhouse gases. CO2 levels are rising day by day, posing a major environmental threat, particularly to agricultural crops. A study found that when seedlings were treated with NPs under high CO2 stress, the majority of the NPs accumulated on the surface of the roots, resulting in a decrease in root hydraulic conductivity, reduced water availability and transpiration rate, and repressed plant growth. Wheat seedlings treated with higher levels of CO2 developed more root mass and lateral roots than those treated with lower levels of CO2. Overall, this work suggests that an increase in CO2 levels would change how nTiO2 affects crop nutritional composition and soil microbial population function, with unknown effects for future human health and economics.

Nano coating and packaging

Higher crop yields and enhanced agricultural sustainability result from nano-coatings' ability to promote controlled nutrient release and antimicrobial protection, which guarantees ideal early-stage plant growth. In addition to improving seeds, nano-enabled smart packaging is essential for decreasing post-harvest losses by prolonging the shelf life of perishable grains, fruits, and vegetables. Cutting-edge nano-packaging materials that contain oxygen scavengers and antibacterial nanoparticles assist delay ripening, minimise microbial contamination, and lessen food spoiling, increasing food security and reducing waste . The creation of environmentally benign and biodegradable nano-coatings and packaging materials is anticipated to advance agricultural sustainability as research advances, guaranteeing food safety and effective long-term storage.

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NEGLECTED AND UNDERUTILIZED CROPS (NUS)

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Abstract

Neglected and Underutilized Crops (NUS) often termed as "orphan crops" are pivotal to address 21st century agricultural challenges especially in megadiverse countries represent a valuable reservoir of genetic diversity, climate resilience and nutritional potential. Despite their significance to marginal communities and traditional food systems, these crops remain under represented in research, policy and commercial agriculture. This article reviews the importance of NUS in the context of food security, climate change adaptation and agricultural sustainability realizing the vision of an Evergreen Revolution a transformation toward productivity with sustainability.

1. Introduction

Modern agriculture has largely focused on a few staple crops wheat, rice and maize resulting in genetic erosion and dietary monotony. In contrast, Neglected and Underutilized Crops (NUS) such as millets, amaranth, buckwheat and pigeon pea have adapted over centuries to local environments offering high resilience to stress conditions and nutritional richness.

2. Importance of Neglected and Underutilized Species (NUS)

2.1 Nutritional Security

Neglected and underutilized species (NUS) contribute significantly to nutritional security especially in regions prone to malnutrition. Many of these crops are naturally rich in essential micronutrients and bioactive compounds.

- Finger millet (*Eleusine coracana*) is an excellent source of calcium and iron making it beneficial for bone health and anemia prevention.
- Amaranth (*Amaranthus spp*.) contains high quality protein and lysine, an essential amino acid often lacking in staple cereals.

By promoting the cultivation and consumption of NUS, communities can enhance dietary diversity and address hidden hunger particularly in rural and tribal regions.

Strong Crops for a Changing Climate

Climate change is making farming harder, rains are unpredictable, temperatures are rising and soils are getting tired. Neglected and underutilized species (NUS) are naturally strong and well-suited for tough conditions. Many NUS grow well in poor soils, need less water and can survive high temperatures. This makes them perfect for climate-smart farming.

For example:

- Kodo millet and little millet thrive with minimal rainfall.
- Bajra (pearl millet) grows well in sandy and dry areas.

By growing these hardy crops farmers can reduce risk, ensure food security and protect their livelihoods even in difficult weather.

Protecting Nature and Traditions

Neglected and underutilized crops (NUS) are not just about food, they are a part of our heritage and biodiversity. These crops have been grown by our ancestors for generations, often using traditional methods that are friendly to the environment.

By growing NUS, farmers can

- Protect agro-biodiversity-a wide variety of plants that keeps farms healthy and pests in check.
- Preserve local knowledge such as seed saving, natural pest control and time-tested farming wisdom.
- Many NUS crops are used in festivals, local dishes and home remedies that connect us to our roots.

NUS in a Megadiverse Bioeconomy

Strategic Area	Action Points
Genetic Resource Conservation	Ex situ and in situ conservation through

	gene banks and community seed banks
R&D Investment	Climate-resilient varieties, biofortification and digital agronomy tools
Market Integration	GI tagging, e-commerce, FPO development and public procurement
Education & Awareness	Awarness campaigns
Institutional Policy	Inclusion in food security programs, crop insurance and subsidies.

3.Barriers in Adoption

Despite their many benefits, neglected and underutilized species (NUS) are still not widely grown or consumed due to different problems like:

- Quality seeds are hard to find and farmers may not have guidance on how to grow them well.
- There's very little investment in research or government policies that promote these crops.
- Unlike wheat or rice many NUS crops are harder to process and don't have strong supply chains.
- To truly unlock the potential of NUS we need more awareness, research, market support and policy action.so these hidden gems can shine on our farms and plates.

Conclusion

Reviving NUS is not merely about crop diversification. it's about reclaiming lost knowledge, empowering local communities and ensuring resilient food systems in a changing climate. With appropriate investment, policy focus and stakeholder collaboration, NUS can play a pivotal role in sustainable agriculture and rural livelihoods.

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UNDERSTANDING MONSOON RAINFALL IN INDIA: AN IN-DEPT EXPLORATION OF ITS CAUSES, TYPES, IMPACT ON AGRICULTURE AND ITS MANAGEMENT

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Abstract

Monsoon rainfall in India is a critical climatic phenomenon, accounting for nearly 70% of the country's annual precipitation and sustaining its agriculture and economy. Driven by temperature differences between land and sea, Tibetan Plateau heating, oceanic pressure systems like the Mozambique High, and global wind patterns, the monsoon manifests in two phases: the South-West Monsoon (June–September) and the North-East Monsoon (October–December). Western disturbances also contribute to off-season rainfall. While vital, monsoon variability poses significant challenges, impacting crop yields, water resources, and rural livelihoods, necessitating effective prediction and management strategies to mitigate risks and ensure agricultural sustainability.

Keywords: Indian monsoon, ITCZ, Seasonal wind shifts, Jet stream, Southwest monsoon.

Introduction

Every year, as dark clouds gather over the Indian subcontinent, they carry more than just rain they bring hope. For millions of farmers across the country, the monsoon is not just a season; it is a lifeline. With nearly 70% of India's yearly rainfall arriving during this time, monsoon showers play a central role in shaping the country's agriculture, economy, and the lives of rural communities. The Indian monsoon is a powerful and intricate climate system, influenced by oceans, winds, and shifting global weather patterns.

Monsoon rains are vital for growing staples like rice, wheat, pulses, and sugarcane especially in regions that rely entirely on rainfall. But the monsoon doesn't always follow the

script. Sometimes it arrives late, pauses unexpectedly, or pours too much too quickly. This unpredictability makes life difficult for farmers, who depend on timely and steady rains to sow, grow, and harvest their crops. And now, with climate change throwing in more uncertainty, the stakes are even higher. Erratic rainfall, shifting monsoon cycles, and extreme weather events are no longer rare they're becoming the new normal. That is why understanding how the monsoon works, how it affects agriculture, and how we can better prepare for its moods is more important than ever. In this article, we take a closer look at the types of monsoon rainfall in India, how it impacts farming, and the evolving strategies being used to manage its variability so that Indian agriculture can stay resilient in the face of a changing climate.

Causes of Indian Monsoon Rainfall

Monsoon rainfall in India is mainly triggered by the following reasons:

1. Temperature difference between land and sea

The specific heat capacity of land and sea is different. In hot season, the subcontinent gets heated fast and creating a low pressure above the land area whereas the sea water take time to get heated and creating a high pressure above the sea water. Due to the pressure difference, the wind moves from higher air pressure to lower air pressure i.e. from sea to land direction along with the moisture-laden winds.

2. Shifting of ITCZ (Inter-Tropical Convergence Zone) towards northern hemisphere

As the Earth rotates around the sun, the ITCZ doesn't stay fixed. During the northern hemisphere summer from June to September, the sun's apparent position moves northward, and so does the ITCZ. This northward shift of the ITCZ plays a crucial role in triggering the Indian monsoon. As it moves over the Indian subcontinent, it brings with it moisture-laden winds from the Indian Ocean, especially the southwest monsoon winds.

3. Enormous heating of Tibetan plateau during March to May

Between March and May, as the sun begins to shine more directly over the Northern Hemisphere, the Tibetan Plateau often called the "Roof of the World" begins to heat up intensely. The strong summer heating of the Tibetan Plateau helps "pull" the monsoon winds inland acting like a giant atmospheric engine that sets the monsoon in motion.

4. Global jet stream flowing across India.

High above the Earth's surface, around 9 to 16 km in the upper atmosphere, powerful rivers of fast-moving air called jet streams sweep across the globe. These narrow bands of wind, driven by

temperature differences between the equator and the poles, strengthens the low-pressure system over the subcontinent and supports the inflow of southwest monsoon winds.

5. Persistent high pressure over Mozambique stream

The warm waters between southeastern Africa and Madagascar, lies the Mozambique Channel; a stretch of ocean that quietly plays a role in India's rainy season. Throughout the year, this region is dominated by a persistent high-pressure system, often referred to as the "Mozambique High". The Mozambique High helps generate southeasterly trade winds over the Indian Ocean. As these winds move northward and cross the equator, the Coriolis effect causes them to turn into the southwest monsoon winds that eventually bring rainfall to India.

Types of Indian monsoon rainfall

India experiences two distinct monsoon periods:

1. South West Monsoon Rainfall

This "summer monsoon" arrives in early June, entering from Kerala, and dominates India's rainfall until mid-October. It is responsible for almost 70% of India's annual rainfall, with the Western Ghats, Northeast India, and the Indo-Gangetic plain receiving the heaviest share. SW monsoon is characterized by heavy downpour and is very important for Indian agriculture and water sources. The SW monsoon splits into two branches upon hitting the Western Ghats: The Arabian Sea branch and the Bay of Bengal branch.

2. North East Monsoon Rainfall

As the south west monsoon begins to fade, the northeast monsoon sets in by October. This monsoon is also known as the "retreating monsoon", the NE monsoon is observed from October to December, bringing moisture-laden winds to parts of South India; mainly Tamil Nadu, Andhra Pradesh, and Telangana. This monsoon wind is flowing from North East direction. It contributes about 10–15% of the Indian annual rainfall.

An interesting anomaly is seen in Tamil Nadu: while the state lies in the rain shadow of the Western Ghats during the SW monsoon (thus remaining dry), it receives much of its rainfall from the NE monsoon.

Aspect	South-West Monsoon	North-East Monsoon
Direction	Sea to land (SW to NE)	Land to sea
Moisture	Moist air brings significant rainfall	Drier winds, less rainfall

Aspect	South-West Monsoon	North-East Monsoon
Coverage	Covers most of India	Specific southern states
Rainfall Share	~70% of annual rainfall	~10–15% of annual rainfall

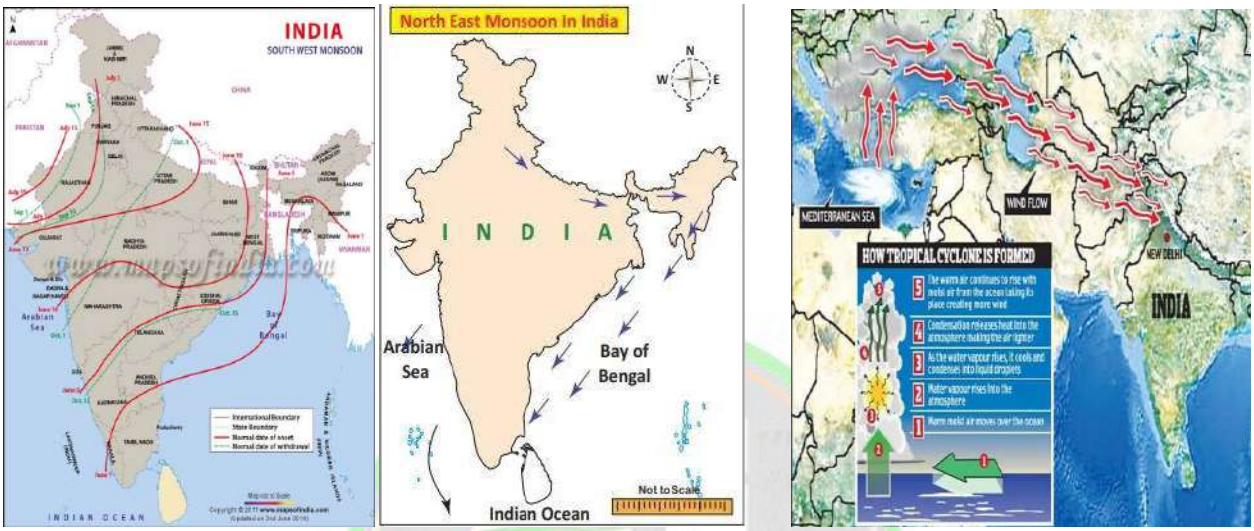

Fig.: Map of onset of Southwest Monsoon Rainfall and Northeast Monsoon Rainfall, and Western Disturbance.

(Source: www.mapofindia.com, www.dristiias.com, www.lotusarise.com)

Western Disturbance

Western disturbances are the low-pressure systems that form in the Mediterranean region and travel to eastward towards the Indian subcontinent. They are driven by the westerlies, which are fast moving air currents in the upper atmosphere. They are characterized by their ability to bring non-monsoonal precipitation, primarily during winter season. It also causes pre-monsoon rainfall especially in North India.

El Nino and La Nina and its impact on Indian monsoon

El Nino is an unusual warming of the central/eastern Pacific Ocean water, weakens Indian monsoon by altering Walker circulation, often causing reduced rainfall, drought, and heat waves. It delayed the onset of monsoon and causes agricultural stress.

La Nina is an unusual cooling of central/eastern Pacific. It strengthens monsoon winds, often leading to above-normal rainfall, floods, and stronger cyclones. It usually brings early onset of Indian monsoon.

Impact on Agriculture

Monsoon rains are a lifeline for Indian agriculture. Timely, well-distributed rainfall ensures optimal soil moisture for crop growth, boosts yields, and replenishes groundwater. However, irregularities such as delayed onset, prolonged breaks, or sudden excess can prove disastrous, leading to crop failure, soil erosion, or even famine. The Southwest monsoon is crucial for Indian agriculture, providing the majority of the country's rainfall and supporting Kharif crop season. A timely and robust monsoon ensures sufficient water for irrigation, replenishes underground, and can lead to higher crop yields and improved rural economics. The Northeast monsoon provides crucial rainfall to southeast India, especially Tamil Nadu, aiding rabi crop sowing, irrigation, and groundwater recharge. It benefits rice, pulses, sugarcane, and plantation crop, supports double cropping, boosts horticulture, replenishes reservoirs, and mitigates drought, ensuring agricultural sustainability during the otherwise dry post-southwest monsoon period. The western disturbances are vital for replenishing Himalayan glaciers, which feed major rivers in the region, and also provide rainfall for Rabi crops in the Northwest India.

Major Challenges Due to Monsoon Variability

Farmers face extreme risks like:

- Floods: Destroy standing crops, erode fertile soil, and cause lasting agricultural damage.
- Droughts: Cause crop failure, reduce water availability, and escalate farming costs.
- Unpredictability: Makes planting schedules uncertain, impacting agricultural planning and income stability.

Mitigation and management of Indian monsoon

Mitigation of monsoon rainfall in India involves flood control structures, rainwater harvesting, and efficient reservoir management. Crop planning with tolerant varieties, early warning systems, and watershed management reduce risks. Urban drainage upgrade, disaster preparedness, and efficient irrigation ensure water use in dry spells. Climate adaptive policies integrate rainfall variability into agriculture, water, and disaster management.

Some monsoon mitigation in India

1. Haryana & Rajasthan – **Indira Gandhi Canal Project** channels monsoon and Himalayan River water to arid region; check dams for water storage.
2. Uttar Pradesh & Bihar – **Embarkments along Ganga & Kosi rivers** to manage annual monsoon floods; river training works.

3. Assam & Northeast – **Brahmaputra Flood Management Project** with embarkments, dredging, and raised platforms for flood-safe shelter.
4. Andra Pradesh – **Polavaram Project** for irrigation and flood moderation; cyclone shelters along coast.

Conclusion

The monsoon's timely arrival, duration, and distribution are pivotal for India's food security and rural livelihoods. Understanding its dynamics and developing adaptive management strategies have never been more significant, given climate variability. By integrating tradition and innovation like forecasting technologies alongside local wisdom India stands better prepared to safeguard its agricultural sector and millions of dependent farm families.

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SILICON: THE SECRET NUTRIENT POWERING PLANT RESILIENCE

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Abstract

Drought and salinity are among the most critical abiotic stresses that limit agricultural productivity worldwide, particularly in arid and semi-arid regions. These stressors disrupt physiological and metabolic processes in plants, leading to reduced growth, impaired nutrient uptake, oxidative damage, and ultimately yield loss. Recent research highlights the pivotal role of silicon (Si) as a beneficial element in enhancing plant tolerance to these environmental constraints. Although not deemed essential for plant growth, Si significantly contributes to stress resilience by reinforcing both structural and functional plant attributes. Silicon-mediated mitigation of drought and salinity involves a synergistic network of physiological, biochemical, and molecular responses. Si enhances water uptake and retention by improving root architecture and reducing transpiration losses through cuticle thickening and stomatal regulation. Under saline conditions, Si mitigates ionic toxicity by restricting Na^+ uptake and facilitating K^+ homeostasis, thereby maintaining ionic balance. It also modulates antioxidant defense systems by upregulating enzymes like superoxide dismutase, catalase, and peroxidase, reducing reactive oxygen species (ROS) accumulation and oxidative stress. Additionally, Si contributes to osmotic adjustment, maintain Na^+ uptake, stabilizes cell membranes, enhances photosynthetic efficiency, and modulates stress-responsive gene expression. This seminar explores the comprehensive role of Si in conferring drought and salinity tolerance, heavy metal toxicity reduction and lodging resistance in crop plants, with emphasis on its application as a sustainable and environmentally

friendly amendment in salt-affected and water-limited soils. Understanding these mechanisms offers valuable insights for developing resilient cropping systems in the face of escalating climate variability and soil degradation.

Keywords: Silicon, Dought, Salinity, Sodium uptake, Water Use Efficiency.

Silicon as a beneficial nutrient for plants

The second most prevalent element in the crust of the earth is silicon (Si). Si was once thought to be a useful but non-essential element. Si was recently listed as a "quasi-essential" element by the International Plant Nutrition Institute. Si is absorbed by plants as soluble silicic acid [$Si(OH)_4$] under less pH < 9. Plants have been shown to benefit from Si supplementation in a number of ways, including increased yield, disease resistance, and reduced abiotic stress. Numerous stressors, including as salinity, elevated temperatures, powdery mildew, hyperhydricity and herbivores, have been documented to be mitigated by the addition of Si nutrition.

Si is frequently observed in soil as silicon dioxide (SiO_2). Wollastonite's prismatic crystals are the main form of calcium silicate and because of the high calcium Pulverised wollastonite and silicate are primarily used in various Si investigations. Despite having higher Si content, magnesium silicate is not a good source for silicon fertiliser because of its poor solubility. Compared to solid Si, liquid Si formulation is simpler to apply at controllable rates. When using both potassium and sodium silicate solutions, foliar application of Si is recommended. Si has advantages in increasing the amount of chlorophyll and the ultrastructure of chloroplasts, which in turn increases the photosynthetic activity of plants. Consequently, it is widely believed that Si is an essential component for controlling the growth and vigour of different plant species is due to its relationship to the morphological, physicochemical, molecular, and nutritional characteristics of plants. In order to improve plant H_2O status, Si is also advantageous for increasing relative water content and transpiration rate.

The beneficial effects of Si include a decrease in water loss by transpiration or cuticles and the deposition of silicate crystals beneath the epidermal cells of leaves and stems. This decrease in drought-related water loss circumstances is mostly ascribed to the interplay between cuticular water permeability and stomatal control. Even when accumulated in excess, silicon can benefit plants in a variety of ways without causing immediate harm. However, under ideal developmental conditions such as adequate light, humidity, water, temperature, etc. Silicon-

induced benefits diminish and become more noticeable in response to stressful situations. This article highlights the role of silicon in mitigating abiotic stresses such as salinity, drought, and heavy metal toxicity in plants, while intentionally excluding its functions in managing biotic stresses like pests and pathogen.

Physiological benefits of silicon under abiotic stress

Plants' defence mechanisms against abiotic stresses enhance their growth and metabolism. Si supplementation was mostly used to mitigate adverse environmental stressors. Silicon reduces biotic stresses like diseases and pests and abiotic stressors like drought, salt, and metal toxicity.

Silicon: A versatile component for reducing plant drought stress

It is widely known that plants exhibit Si-triggered enhancement of biological, physiological, and biochemical characteristics when they are water-deficient. The two primary Si-mediated mechanisms to enhance physical and mechanical protection are SiO_2 deposits and a biological mechanism that promotes metabolic changes. Plant resistance to adversity. Improved morphology has been linked to Si's ameliorative effect against drought stress by reforming and granting the exceptional regulation of diverse morphological and physicochemical responses.

Si in soil salinity

Si helps to decrease the soil salinity by enhancing the plant's defenses against biotic and abiotic stressors. It also, increases the stress tolerance in plants by means of decreasing electrolyte leakage and malondialdehyde content, scavenging the harmful effects of ROS, and minimizing excessive uptake of Na ions in sodic soil (Rizwan et al., 2023). A solid amorphous silica that offers structural stability and mechanical support is formed when silicic acid, an organic source of silicon, enters plant tissues through aquaporin. In saline soils, silicic acid's solubility and low acidity aid in preventing drought (Lacerda et al., 2022).

Si in lodging resistance

The stiffness of rice stalks has been associated with silicon, which can make them more rigid and enhance their resistance to bending or lodging, reducing crop loss and increasing harvest expenses. Silicon buildup is remarkably positively correlated with lodging resistance and the amounts of cellulose and lignin in stalks (Wei et al., 2024). It is known that rice plants can accumulate large levels of silicon—up to 10% in the shoot. In order to defend against a range of biotic and abiotic stresses, the plant need this accumulated silicon. Silica-deposited rice plants

have longer vascular bundles and thicker culm walls, which may help prevent lodging. According to research, a cultivar that is resistant to lodging has a higher silicon content in its culm epidermis than a cultivar that is susceptible to it. It has long been known that silicon has a favorable effect on plant growth, especially in stressed environments.

Reduction of heavy metal toxicity

Si application reduce the heavy metal toxicity by reduce the apoplasmic transport of metals by decreasing free metal concentration in the apoplasm. Physical barrier formed by the deposition of Si in the vicinity of the endoderm may reduce the cell wall porosity of inner root tissues, thus reducing the metal concentration in the xylem. Silicon accumulation in the roots endodermis may reduce the mobility of heavy metals such as As and Cd.Si application enhance the activity of gas exchange characteristics (net photosynthetic rate (Pn), stomatal conductance (Gs), transpiration rate (Tr) and water use efficiency) and photosynthetic pigments under heavy metal stress.

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DEVELOPING NUTRIENT-RICH PURE LINES: BREEDING STRATEGIES FOR SELF-POLLINATED VEGETABLE CROPS

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Abstract

The global challenge of hidden hunger-micronutrient deficiency despite sufficient calorie intake-has driven the development of nutrient-rich pure lines in self-pollinated vegetable crops. Pure line breeding provides a genetically stable method to enhance key nutrients such as iron, zinc, provitamin A, folate, and antioxidants in crops like tomatoes, beans, peas, lettuce, and peppers. Traditional methods, supported by modern molecular tools like marker-assisted selection and QTL mapping, have enabled the release of biofortified varieties with proven health benefits. While challenges remain in balancing nutrition with agronomic performance, pure line development offers a sustainable solution to address global micronutrient deficiencies.

Introduction

The global challenge of hidden hunger-where populations has adequate caloric intake but lack essential micronutrients-has sparked a revolution in vegetable breeding. Pure line development has emerged as a cornerstone strategy for creating genetically stable, nutrient-dense vegetable varieties that can address widespread nutritional deficiencies while maintaining agricultural viability (Ebert 2020). Pure line breeding, first systematically described by Wilhelm Johannsen in 1903 through his groundbreaking work on common beans (*Phaseolus vulgaris*), exploits the natural self-pollinating tendency of numerous vegetable crops. This breeding approach has proven particularly effective for developing nutritionally enhanced varieties of

tomatoes (*Solanum lycopersicum*), common beans (*Phaseolus vulgaris*), garden peas (*Pisum sativum*), lettuce (*Lactuca sativa*), and peppers (*Capsicum annuum*) crops that collectively provide essential nutrients to billions of people worldwide (Weiss and Gruda 2025). Currently, the most common micronutrients targeted are iron, zinc, and provitamin A carotenoids, due to the high prevalence of deficiencies among vulnerable populations globally. The genetic stability inherent in pure lines makes them ideal vehicles for delivering consistent nutritional benefits across generations, while their self-pollinating nature ensures that farmers can save and replant seeds without losing enhanced nutritional traits.

Classical Pure Line Development Methodologies

The development of nutrient-rich pure lines relies on systematic breeding approaches that exploit the genetic uniformity achievable in self-pollinated crops. These methodologies have been refined over more than a century of plant breeding experience and continue to form the foundation of modern nutritional enhancement programs.

The Pedigree Method provides a systematic approach for tracking superior lineages through multiple generations. Each selected plant's ancestry is carefully recorded, allowing breeders to identify the most promising genetic backgrounds for nutritional enhancement. This method has proven particularly effective for developing tomato varieties with enhanced lycopene content, where specific genetic lineages consistently produce high-carotenoid offspring (Mishra *et al.*, 2023).

Bulk Population Method offers an efficient approach for handling large segregating populations in early generations. This method allows natural selection to eliminate poorly adapted genotypes while maintaining genetic diversity for later selection. In bean breeding programs, bulk populations derived from crosses between high-iron and high-yielding varieties have been successfully used to develop nutritionally enhanced pure lines (Begna, 2021).

Modern Molecular Enhancement of Pure Line Breeding

Contemporary pure line development has been revolutionized by the integration of molecular tools that provide unprecedented precision and efficiency in selecting for nutritional traits. These technologies have dramatically reduced the time and resources required to develop nutritionally enhanced varieties while improving the accuracy of selection decisions.

Molecular Marker-Assisted Selection (MAS) has transformed the efficiency of pure line breeding by enabling breeders to identify plants carrying desired nutritional genes without

waiting for phenotypic expression. This approach is particularly valuable for mineral content traits that require expensive analytical procedures. In iron biofortification programs, DNA markers linked to iron accumulation genes allow early identification of superior genotypes, reducing breeding cycle time from years to months (Maji *et al.,* 2023).

Quantitative Trait Loci (QTL) Mapping has identified chromosomal regions controlling important nutritional traits in major vegetable crops. In tomatoes, QTL for lycopene content have been mapped to specific chromosomal regions, enabling marker-assisted pyramiding of favorable alleles. Similarly, QTL for iron content in beans have been identified and successfully used in breeding programs (Aguilar-Benitez *et al.,* 2022).

Targeting Critical Nutritional Deficiencies Through Vegetable Crop Enhancement

The strategic focus of pure line breeding programs centers on addressing the most prevalent nutritional deficiencies that affect human health globally. Each target nutrient presents unique opportunities and challenges within different vegetable crop species.

1. **Iron Enhancement in Leguminous Vegetables** addresses the widespread problem of iron deficiency anemia affecting over 2 billion people worldwide. Common beans have emerged as a premier target for iron biofortification due to their significant natural variation in iron content and their importance in the diets of vulnerable populations. Plant breeding programs within the CGIAR and NARS have made major advances in Fe- and Zn-dense variety development. Pure line bean varieties with 80-100% higher iron content have been developed and released in multiple countries, with human feeding studies confirming significant improvements in iron status among consumers (Roriz *et al.,* 2020). Garden peas have also shown exceptional potential for iron enhancement, with some pure lines containing over 70% more iron than conventional varieties. The protein-rich nature of peas makes them particularly valuable targets for iron biofortification, as protein can enhance iron absorption when consumed together.
2. **Zinc Biofortification** targets the approximately one-third of the global population affected by zinc deficiency. Beans and peas have demonstrated significant potential for zinc enhancement through pure line breeding. Enhanced zinc varieties typically show 40-70% higher zinc content while maintaining acceptable cooking characteristics and yield performance. The bioavailability of zinc from these enhanced varieties has been

confirmed through bioavailability studies, demonstrating real nutritional impact (Buturi *et al.*, 2021).

3. **Provitamin A Carotenoid Enhancement** focuses primarily on tomatoes and peppers, which naturally contain significant levels of beta-carotene and other carotenoids. Carotenoid biofortification in tomato products has achieved remarkable success, with orange-fleshed tomato varieties containing 10-15 times more beta-carotene than conventional red varieties. These varieties maintain acceptable processing characteristics for sauce and paste production while delivering enhanced vitamin A precursor content (Kalia and Singh 2018).
4. Pepper varieties have been developed with enhanced carotenoid profiles, including increased levels of zeaxanthin and capsanthin, which provide both nutritional benefits and improved color stability in processed products.
5. **Folate Enhancement in Leafy Vegetables** addresses the critical need for increased folate intake, particularly among women of reproductive age. Lettuce pure lines with 2-3-fold higher folate content have been successfully developed while maintaining shelf life and sensory characteristics required for commercial fresh-cut operations. These varieties provide significant folate content in typical serving sizes, contributing meaningfully to daily folate requirements (Geetha *et al.*, 2022).
6. **Antioxidant Compound Enhancement** extends beyond essential vitamins and minerals to include beneficial phytochemicals with health-promoting properties. Pure line tomato varieties with enhanced levels of lycopene, chlorogenic acid, and flavonoids have been developed through systematic breeding approaches. These compounds contribute to chronic disease prevention while adding value to processed tomato products (Rai *et al.*, 2012).

Challenges and Solutions in Nutrient-Rich Pure Line Development

Despite significant successes, developing nutrient-rich pure lines faces several persistent challenges that require innovative solutions and continued research investment.

1. **Balancing Nutritional Enhancement with Agricultural Performance** represents the primary challenge in pure line development. Enhanced nutritional varieties must maintain yield potential, disease resistance, and stress tolerance required by farmers. This balance

requires extensive field testing and may necessitate accepting moderate improvements in nutritional content to preserve essential agronomic characteristics.

2. **Ensuring Nutritional Bioavailability** extends beyond simply increasing nutrient concentrations to ensuring that enhanced nutrients can be effectively absorbed and utilized by the human body. Antinutrients present in some vegetables can reduce mineral absorption, requiring breeding strategies that simultaneously increase beneficial nutrients while reducing inhibitory compounds.
3. **Environmental Stability of Nutritional Traits** poses ongoing challenges as environmental factors can significantly influence nutritional content. Breeding programs must develop varieties that maintain nutritional advantages across diverse growing conditions and management practices.

Understanding Self-Pollinated Vegetable Crops: The Foundation for Pure Line Success

Self-pollinated vegetable crops possess unique reproductive characteristics that make them exceptionally suited for pure line development. These crops complete fertilization primarily using their own pollen, resulting in offspring that are genetically nearly identical to their parents. This reproductive strategy provides several critical advantages for nutritional breeding programs.

1. **Tomatoes (*Solanum lycopersicum*)** represent one of the most successful examples of pure line breeding for enhanced nutrition. Tomato fruits are an important source of bioactive compounds, including lycopene, beta-carotene, vitamin C, and various phenolic compounds. The self-pollinating flowers of tomatoes, which typically fertilize before opening, ensure genetic stability in enhanced varieties. Modern tomato pure lines have been developed with dramatically increased carotenoid content, some containing up to 15-fold higher beta-carotene levels than conventional varieties (Sharma *et al.*, 2019).
2. **Common beans (*Phaseolus vulgaris*)** showcase the power of pure line breeding for mineral enhancement. Beans are naturally self-pollinating, with fertilization occurring before flower opening in most varieties. This characteristic has enabled breeders to develop iron-biofortified bean varieties with 80-100% higher iron content than conventional types. These enhanced varieties maintain their nutritional superiority across generations without requiring complex seed production systems (Bhattacharjee *et al.*, 2024).

3. **Garden peas (*Pisum sativum*)** hold historical significance as Mendel's original model organism and continue to serve as an excellent example of pure line breeding potential. Pea (Pisum sativum L.) is a widely grown pulse crop that is a source of protein, starch and micronutrients in both human diets and livestock feeds. Modern pea breeding has focused on enhancing protein quality, increasing zinc content, and improving starch digestibility through pure line development (Abdel-Hamid *et al.,* 2021).
4. **Lettuce (*Lactuca sativa*)** demonstrates the application of pure line breeding to leafy vegetables. Societal awareness of healthy eating is increasing alongside the market for processed bagged salads, creating demand for nutritionally enhanced varieties. Pure line lettuce varieties have been developed with enhanced folate content, improved antioxidant profiles, and extended shelf life characteristics (Hassan *et al.,* 2021).
5. **Peppers (*Capsicum annuum*)** offer exceptional opportunities for carotenoid enhancement through pure line breeding. The wide color variation in peppers—from green to yellow, orange, and red—reflects differences in carotenoid content that can be exploited for nutritional enhancement. Pure line pepper varieties with enhanced vitamin C and carotenoid levels have been successfully developed while maintaining desired flavor profiles (Devi *et al.,* 2021).

Conclusion

The development of nutrient-rich pure lines through advanced breeding strategies represents a sustainable, scalable solution to global nutritional challenges. The genetic stability of pure lines ensures that nutritional benefits persist across generations, while their compatibility with traditional farming systems makes them accessible to smallholder farmers worldwide. Success stories from iron-rich beans in East Africa to high-carotenoid tomatoes in processing industries demonstrate the practical viability of this approach. International research efforts, including those funded by Harvest Plus, are focusing on conventional plant breeding to biofortify staple crops including vegetables, showing the growing global commitment to nutritional enhancement.

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ROLE OF MICROORGANISMS IN WASTEWATER TREATMENT PLANTS

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Abstract

This article discusses the vital function of microorganisms in wastewater treatment plants. Microorganisms including aerobic, anaerobic, and facultative bacteria are responsible for decomposing organic and inorganic contaminants in different stages of treatment. Treatment has been divided into primary, secondary, and tertiary treatment steps that make use of particular microbial processes. Membrane technologies and microbial engineering are gaining ground as more advanced biotechnological strategies to enhance treatment efficiency. Microbes are responsible for lowering biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), fats, oils, and grease (FOG), and even odor removal. The paper also covers emerging microbial applications such as bio-augmentation, microbial fuel cells, and smart sensors. Ongoing research in microbial wastewater treatment promises sustainable environmental management and cleaner water systems.

Keywords : Wastewater treatment, Microorganisms, Aerobic bacteria, Anaerobic bacteria, Facultative bacteria, Biochemical Oxygen Demand (BOD), Constructed wetlands, Biotechnological engineering, Microbial bio-augmentation.

Indroduction

Wastewater has been defined as water contaminated and no longer useful, and hence not to be discharged into the environment in its untreated form. If the wastewater is to be utilized for any useful purpose or discharged into the environment, it needs to go through various treatment processes to avoid adverse effects. There are primarily four categories of wastewater: domestic

or municipal wastewater, industrial wastewater, urban runoff, and agricultural runoff. Microorganisms play a crucial role to break down inorganic and organic pollutants in wastewater treatment. Microorganisms are the essence of three major groups of biological systems for wastewater treatment:

1. Fixed Film Systems – where microorganisms are attached to surfaces (e.g., Trickling Filter Beds and Rotating Biological Contactors).
2. Suspended Film Systems – in which microorganisms are suspended in the water column (e.g., Activated Sludge, Membrane Bioreactors, Facultative Stabilization Ponds, and Constructed Wetlands).
3. Free Water Surface Systems – that mimic natural systems such as wetlands to treat water through microbial and plant interactions

Besides these conventional methods, novel biotechnological processes—such as bio-augmentation, microbial consortia, and genetically modified strains—are now employed in advanced wastewater treatment plants for optimizing efficiency and enabling sustainable water management.

COMMON MICROORGANISMS USED IN WASTEWATER TREATMENT PLANTS

Aerobic Bacteria

Aerobic bacteria grow well in the presence of oxygen. They are very good at utilizing organic pollutants, such as proteins, carbohydrates, and fats. They are able to reduce complex substances into simpler ones, and wastewater treatment is more effective. For instance, Pseudomonas and Bacillus species can easily degrade hydrocarbon, hence they are required in wastewater treatment from oil and petroleum-related industries.

Anaerobic Bacteria

Anaerobic bacteria are present in low-oxygen regions and are experts in degrading intricate organic chemicals by anaerobic digestion. One of the by-products of this is methane gas, which is an effective renewable energy source. Such dual purpose makes anaerobic bacteria crucial for the treatment of high-strength industrial wastewater with both pollution removal and energy production. For instance, Methanogens promote increased methane production, which is essential for national sustainable development goals (SDGs).

Facultative Bacteria

Facultative bacteria are capable of living in both oxygen-rich and low-oxygen

environments. Their versatility renders them useful for use at any stage of wastewater treatment, effectively lowering organic material and nutrients. Current research is investigating their entire potential in wastewater treatment plants. Proper growth requires them to be under certain conditions of temperature, pH, oxygen levels, and availability of nutrients.

MECHANISM USED

Primary Treatment

In this initial stage, physical processes like screening and sedimentation remove large solid materials and grit from sewage. While the main focus is solid waste removal, some organic matter is also eliminated. Microorganisms, especially bacteria, contribute by enzymatically breaking down organic materials

Secondary Treatment:

This process is where microbiological activity takes the center stage. It deals with the elimination of dissolved and suspended organic contaminants, nutrients such as nitrogen and phosphorus, and other pollutants that pollute aquatic environments. It encompasses:

i) Aerobic Treatment:

Aerobic Treatment is conducted under aerobic conditions, aerobic microorganisms, mainly bacteria, break down organic matter into carbon dioxide, water, and microbial biomass via aerobic respiration. This process lowers the biological oxygen demand (BOD) of the wastewater considerably, thus decreasing the level of harm the wastewater will cause to the receiving aquatic ecosystem or water bodies. Nitrifying bacteria are the main actors in aerobic treatment and play a role in the conversion of ammonia (ammonia is one of the most prevalent pollutants in sewage) into nitrite and nitrate via nitrification.

ii) Anaerobic Treatment

In the absence of oxygen, anaerobic microorganisms (bacteria and archaea) break down organic matter through anaerobic digestion. This produces biogas (mainly methane), which can be used as renewable energy. Anaerobic digestion also removes pathogens and organic pollutants.

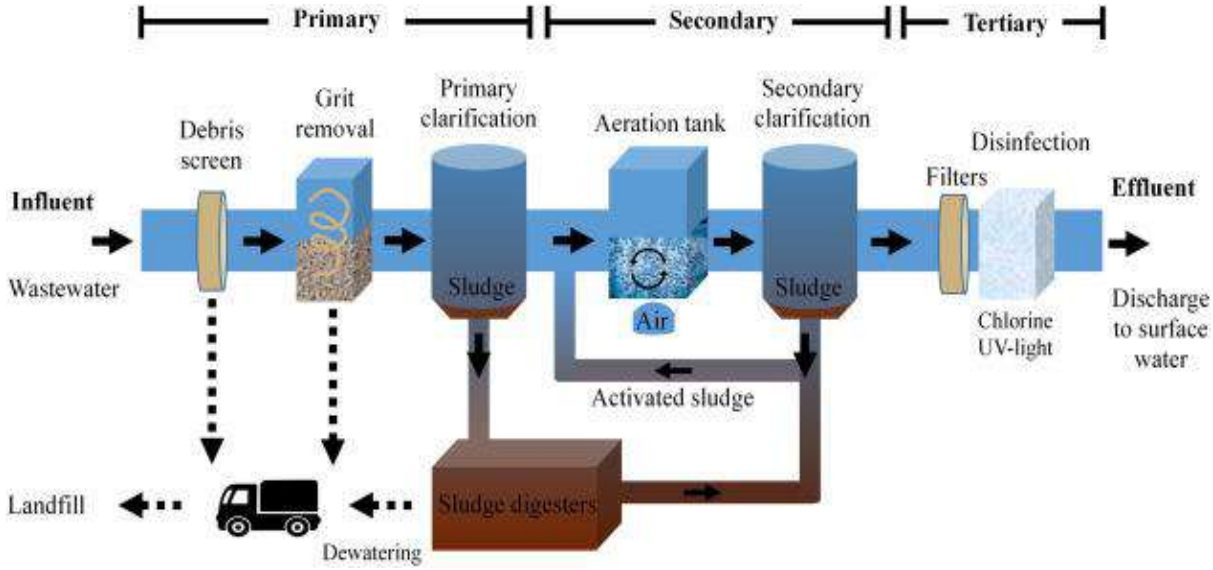
Tertiary Treatment

Tertiary treatment stage is incorporated to further improve the quality of water being treated prior to release into the environment. It can involve other physical, chemical, or biological treatments to eliminate any residual contaminants or toxic substances found in water

bodies. Microorganisms contribute an important part in certain tertiary treatments like bio-filtration and constructed wetlands, where they are used to eliminate nutrients and suspended particulate matter.

BIOTECHNOLOGICAL ENGINEERING

Naturally, microorganisms biodegrade wastewater pollutants. Traditional technologies



that involve microbes—such as Advanced Oxidation Processes (AOPs) and Membrane Separation Technologies—are gaining popularity. Combining these techniques normally results in the most effective treatment and reuse schemes.

RESULTS OF MICROORGANISM USE IN WASTEWATER TREATMENT PLANTS

FOG (Fats, Oil, and Grease) Removal

Aerobic bacteria inhibit the buildup of fats, oils, and grease. Methods such as bio-augmentation are being considered to address localized FOG issues and enhance treatment effectiveness

BOD (Biochemical Oxygen Demand) Reduction

Aerobic bacteria, functioning as biochemical surgeons, identify and lower the biochemical oxygen demand in wastewater. This is significant in avoiding oxygen deficiency in water bodies and ensuring safe aquatic ecosystems.

Reduction of COD (Chemical Oxygen Demand)

Microorganisms used in treatment plants to efficiently break down organic and inorganic contaminants, and therefore reducing the COD levels.

All these advances contribute to environmental conservation and sustainable water resource management in water-scarce regions.

TSS (Total Suspended Solids) Reduction

Secondary treatment stage, are employed in enhancing the process of sedimentation. At sewage treatment works, Delhi, continuous efforts are being made to integrate nature-based solutions, such as constructed wetlands, into the system to make microorganisms more effective in lowering Total Suspended Solids (TSS) concentrations.

Odor Removal

Microorganisms are also responsible for removing foul smells that are characteristic of wastewater treatment. Investigations still go on in investigating bio-filtration systems, such as certain odor-reducing microbial strains to optimize or to refine the sense of smell of wastewater treatment.

Innovation and Future Prospects

With wastewater treatment gaining increasing importance in India's changing scenario, the development of research and innovation keeps on improving microbial applications with the help of bio-films, genetic manipulation of microbes for bioremediation of waste water treatment. Right from microbial fuel cells to create electricity to creating smart microbial sensors for real-time monitoring, there are bright expectations in the future to implement microorganisms in wastewater treatment plants more efficiently.

Conclusion

Microorganisms are essential in wastewater treatment as they decompose organic waste, eliminate waste and nutrients, and clean water. Treatments are particularly prevalent in sewage and household wastewater systems. Environmental factors like temperature, pH, and nutrient content greatly influence microbial effectiveness. Further research is necessary to learn more about microbe-plant interactions as well as improve pollutant removal from aquatic

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SOLAR ENERGY PAVING WAY TOWARDS SUSTAINABLE GROWTH IN RAJASTHAN

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Abstract

Sustainable development necessitates urban and rural planning strategies that harmonize environmental preservation, economic growth, and social equity. Integrating solar energy into urban infrastructures emerges as a pivotal approach. The rapid urbanization observed globally necessitates a paradigm shift towards sustainable development. Integrating solar energy into urban infrastructures emerges as a strategic approach to mitigate environmental impacts, enhance energy security, and promote economic growth. Rajasthan, endowed with high solar irradiance and expansive arid lands, illustrate this integration. The state has launched the Integrated Clean Energy Policy 2024, targeting 125 GW of renewable energy capacity by 2030, including 90 GW from solar power. Notably, the Bhadla Solar Park, spanning 56 square kilometres with a capacity of 2,245 MW, stands as India's largest solar park, contributing significantly to the nation's renewable energy goals. Urban centres like Jaisalmer and Pushkar are being developed as solar cities, incorporating rooftop solar systems, solar-powered street lighting, solar water pumps, solar-Powered Drip Irrigation and electric vehicles, aiming to meet all energy requirements through solar sources. Government Programs in Rural Rajasthan like PM-KUSUM (Pradhan Mantri Kisan Urja Suraksha Evam Utthaan Mah Abhiyan) Target: 17.5 lakh solar pumps in India, major share for Rajasthan, over 1.25 lakh solar pumps installed in rural Rajasthan.60% subsidy support to farmers is provided. Special focus on Barmer, Jalore, Bikaner, Jaisalmer districts, Saubhagya Scheme provided solar kits to remote tribal homes (Dungarpur, Banswara, Pratapgarh). Standalone systems used where grid is not feasible As urban and rural areas

continue to expand, embedding solar energy solutions it is imperative to achieve sustainable development goals and foster environmentally responsible.

Keywords: Sustainable development, urban planning, urban growth, rural growth

Introduction

Sustainable growth refers to development that meets the needs of the present without compromising the ability of future generations to meet their own needs. Solar energy aligns perfectly with this vision, as it offers long-term energy security, economic opportunity, and environmental protection. In an era of growing energy demands, environmental degradation, and climate change, solar energy emerges as a powerful solution that supports sustainable growth. As a clean, renewable, and abundant source of energy, solar power plays a vital role in reducing our dependence on fossil fuels and promoting environmentally responsible development.

Solar energy in urban areas refers to the generation and utilization of solar power within cities primarily through rooftop solar panels, building-integrated photovoltaics and solar powered public infrastructure. Farmers use solar-powered water pumps for irrigation, reducing dependence on costly diesel pumps. This lowers farming costs and improves productivity and food security.

Why in Rajasthan?

Rajasthan is one of the most solar-rich regions in India, making it an ideal location for solar energy generation. Over 300 sunny days a year in Rajasthan and vast stretches of barren, desert, and non-agricultural land are available, allowing the development of massive solar parks like the Bhadla Solar Park (world's largest).

Rajasthan's government has also implemented supportive solar energy policies, such as the Rajasthan Solar Energy Policy 2019 and the Renewable Energy Policy 2023, which provide subsidies, tax benefits, and simplified procedures for solar project development.

Urban areas in Rajasthan, including Jaipur, Jodhpur, and Udaipur, are seeing increasing adoption of rooftop solar systems, solar street lights, and smart solar infrastructure.

The state has developed robust power transmission infrastructure, including Green Energy Rajasthan, known for its vast desert landscapes and high solar irradiance, is one of India's leading states in solar energy production. Urban and rural areas are also increasingly adopting solar energy as part of sustainable growth

Solar projects in Rajasthan

Rajasthan's solar journey is a shining example of how natural endowments, when aligned with visionary policy and private sector participation, can drive sustainable energy transformation. By continuing to invest in infrastructure, farmer participation, and smart policy frameworks, Rajasthan is not just lighting up its own future but also becoming an alarm of clean energy leadership for the rest of India and the world.

source:https://www.earthdata.nasa.gov/news/worldview-image-archive/bhadla-solar-park-india?utm_source=chatgpt.com

NAME OF PROJECT	LOCATION(DISTRICT)	CAPACITY(MW)	KEY FEATURE
BHADLA SOLAR PARK	Jodhpur	2245+MW	One of the worlds largest solar park
Dungargarh solar park	Bikaner	1000 MW	Utility scale, desert solar park
Phalodi solar park	Jodhpur	750 MW	High irradiance zone
Pokhran solar plant	Jaisalmer	300 MW	Near India's border region
Suratgarh solar park	Sri Ganganagar	200 MW	Argo-solar project integration
Kota solar power plant	Kota	120 MW	Urban-industrial solar use
Barmer solar plant	Barmer	100 MW	High solar potential zone
Chhabra solar plant	Baran	50 MW	Linked to thermal plant grid
Udaipur solar project	Udaipur	40 MW	Hilly terrain solar setup
RRECL Rooftop projects	Jaipur& others	varies	Govt buildings and schools

source:https://en.wikipedia.org/wiki/Solar_power_in_India?utm_source=chatgpt.com

Solar irradiance in Rajasthan

Rajasthan is one of the most solar-rich regions in India, making it an ideal location for solar energy generation. The solar irradiance in Rajasthan refers to the power per unit area received

from the Sun in the form of electromagnetic radiation. It is typically measured in kilowatt-hours per square meter per day (kWh/m²/day).

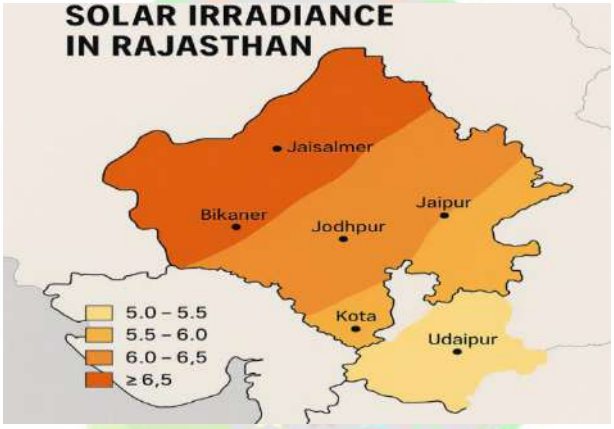
1.High Solar Potential: Rajasthan receives average solar irradiance between 5.5 to 6.5 kWh/m²/day, which is among the highest in India.

2.Geographical Advantage: The vast Thar Desert and arid climate provide minimal cloud cover and dust, ensuring high solar insolation.

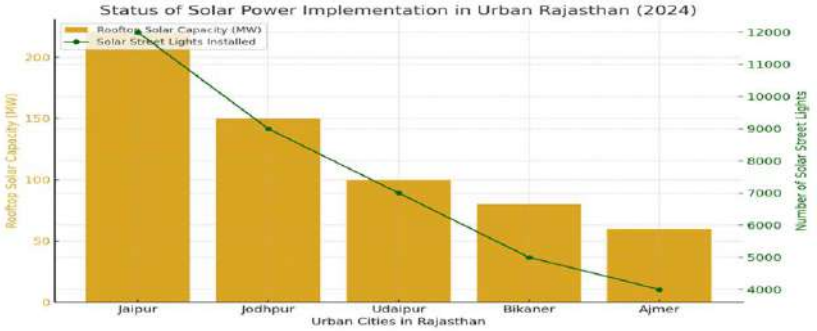
3.Regional Variation:

Western Rajasthan (Barmer, Jaisalmer, Bikaner) receives the highest irradiance (6.0–6.5 kWh/m²/day).

Eastern and southern areas (like Kota and Udaipur) receive slightly lower irradiance (~5.5–6.0 kWh/m²/day), still above the national average



STATUS OF SOLAR POWER IMPLEMENTATION IN URBAN RAJASTHAN (2024)

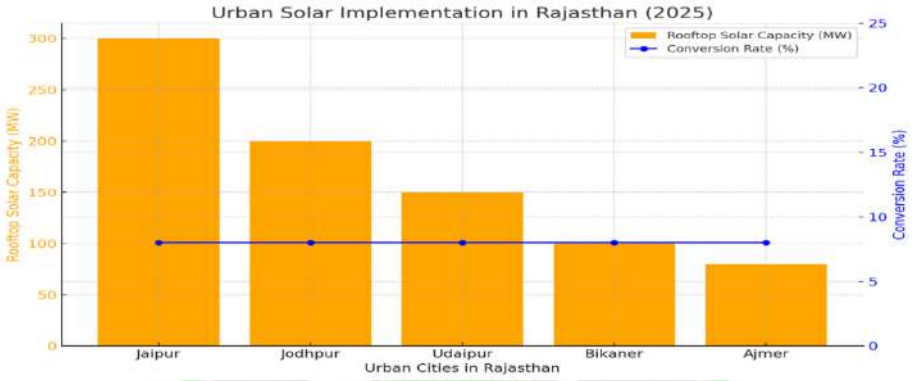


source:https://en.wikipedia.org/wiki/Solar_power_in_India?utm_source=chatgpt.com

Rooftop Solar Capacity (Bar Graph - Yellow Bars, Left Y-axis): Jaipur leads with the highest capacity (~210 MW) followed by Jodhpur (~150 MW), Udaipur (~100 MW), Bikaner (~80

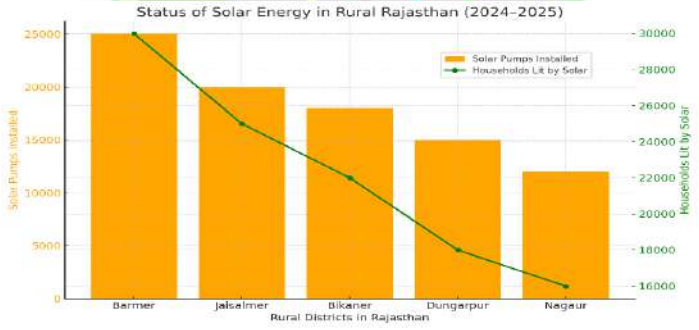
MW), and Ajmer (~60 MW). There is a gradual decline from Jaipur to Ajmer, indicating that Jaipur has the most developed rooftop solar infrastructure among these cities. This graph effectively shows that urban Rajasthan is progressively adopting solar energy, with Jaipur leading, and a declining trend in implementation as we move to smaller or less prioritized cities like Ajmer. This could help identify where future investments or government efforts should focus to balance solar infrastructure across the state.

STATUS OF SOLAR POWER IMPLEMENTATION IN URBAN RAJASTHAN (2025)



The graph shows quantitative growth in solar capacity, but no change in the efficiency or uptake rate across cities. Policy focus may now need to shift from just increasing installed capacity to improving conversion efficiency and utilization in all cities.

STATUS OF SOLAR POWER IMPLEMENTATION IN RURAL AREAS (2024-25)



Barmer is the leading district in both agricultural (solar pumps) and residential (solar lighting) solar adoption. This indicates a strong focus on both farming and household electrification using solar energy in the western Rajasthan desert belt. The decreasing trend highlights where more government and policy focus could improve rural solar penetration (e.g., Nagaur and Dungarpur).

Conclusion

Rajasthan stands as a national leader in solar energy integration due to its vast solar potential, proactive state policies, and large-scale project execution. The state's approach to urban planning, aligned with renewable energy goals, showcases a model of sustainable and resilient development. By embedding solar infrastructure in both urban and rural planning, Rajasthan has not only enhanced energy security but also promoted environmental sustainability, economic development, and social equity. Initiatives like the PM-KUSUM scheme, rooftop solar programs, and the development of smart solar cities like Jaipur and Udaipur demonstrate how clean energy can transform urban ecosystems. The synergy between state initiatives, national missions, and private sector investment has made Rajasthan a pioneer in India's energy transition

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SYSTEM OF RAGI INTENSIFICATION

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Introduction

Finger millet (Eleusine coracana L.) or ragi is an important millet crop grown in low-rainfall rainfed region and resource poor conditions as food for poor people. Among the millet crop finger millet occupies 60 percent of the production area. Finger millet is nutritionally richer than the common cereal crops like rice, wheat etc. Finger millet crop can grow in wider agro-climatic conditions and having the highest production capacity among other millets. However, as compared to its potential, finger millet productivity is less due to poor and harsh environmental conditions for its growth, less use of inputs by resource poor farmers, attention towards major food crops cultivation. However, it can serve as good alternative of major cereal crops especially under the risk of crop failure due to several reasons like water scarcity, poor soil fertility status, adverse agro-climatic conditions, etc. To fulfill the nutritional security of the ever increasing population, there is a need to enhance the production potential of the crop by adopting advanced crop production techniques or modification in the agronomic practices. System of crop intensification attains more attraction among the farming community for increasing the productivity of different crops.

Millets especially finger millet is mostly sown by broadcasting/ random transplanting in dry tracts and less care is paid to it resulting in higher competition for resources and thereby, poor productivity. If millets are cultivated according to system of crop intensification, the competition among plants and weeds for resources can be minimized leading to high growth and yield of crop. System of Ragi Intensification is called as Gulli ragi in local language which

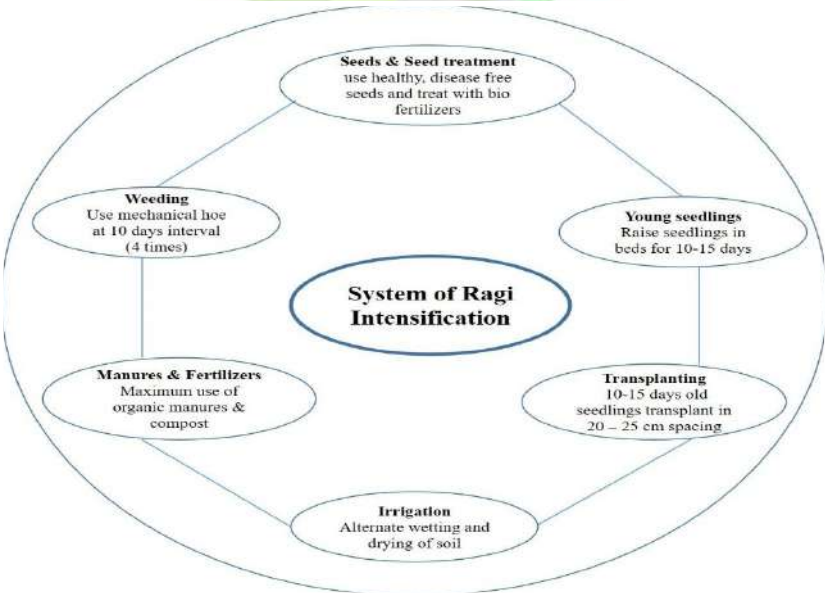
applies the same kind of management practices as used in SRI to grow finger millet, with often tripling of yield, without dependence of chemical fertilizers. SRI technology uses less input, less seed, water, chemical fertilizers and pesticides but uses more organic manures. Rice grown with SRI Technology has large root volume, profuse and strong tillers with big panicles, more and well – filled spikelets with higher grain weight. Under SRI, ragi fields are not flooded but only kept moist by alternate wetting and drying.

The concept of system ragi intensification has emerged from the increased success and popularity of system of rice intensification (SRI) and now this concept is being tried in other crops as well. There are two basic principles in SRI

- Principle of root development (proper nourishment and sufficient space around the plant for better root growth and uptake of nutrients and moisture)
- Principle of intensive care (careful management of soil, agronomic practices in each stage of plant growth).

SRI aims at establishment of young and healthy seedlings for optimum root and shoot growth, reduction in crop population by wider sowing/transplanting for effective utilization of space, light, nutrients and water, etc., improvement of soil health through enriching organic matter, aeration as well as biological environment, use of water for moistening the soil without creating hypoxic condition. All these agronomic practices can improve crop yield and quality.

Principles of System Ragi Intensification



Young Seedlings

Use of young seedlings with the age of 10 – 15 days old having two leaves have to be ensured to produce more tillers and more root growth. It is important to avoid 'shock' or 'trauma' while transplanting the seedlings. Remove seedlings from nursery with seed, soil and roots intact carefully and plant it in the field without plunging too deep into the soil. Care should be taken to ensure that when the seedlings are transplanted that their root tips are not inverted as usually happened during the hurried, rough transplanting done in the conventional method. If the root tip was turned upward – shaped like a J, rather than an L it could take a week or more for the tip to reorient itself downward and resume growth.

Wider Spacing

Ragi plants can better realize their potential for tiller and root growth and for subsequent grain filling, if spaced widely rather than densely. Seedlings are to be planted a square pattern at 25 x 25 cm wide. Leaving wide space between each plant ensures that roots have adequate room to grow and the plants will be exposed to more sunlight, air and nutrients. The result is more root growth and more tillering.

Weeding and Aeration

Use simple mechanical hand weeder (rotary hoe) to churn the soil for weed control. Rotate the weeder at least 2 to 4 times. This incorporates the weeds into the soil. The first weeding should be done at 10-12 days after transplanting to eliminate weeds when these were just germinating rather than wait for them to grow. Subsequent weedings are done at 10 days interval. Working with rotary weeders helps in greater aeration which results in more root growth, reduced weed competition, more oxygen and nitrogen to roots.

Water Management

Regular irrigations needs to be done to keep the soil moist. Alternate 'wetting and drying' should be done which give aerobic and anaerobic soil conditions for better nutrient mobilization by soil biota. This avoids root degeneration, which usually happens under continuous flooding.

Unflooded conditions, combined with mechanical weeding, result in more air in the soil and greater root growth. Higher root growth provides access to more nutrients.

Organic Manures

Encourage the farmers to apply FYM or compost in higher quantity instead of using chemical fertilizers. It is recommended to apply FYM @ 10t/ha which is quite sufficient as a source of nutrients. As a result, more plant growth is achieved because of better soil health and more balanced nutrient supply. Use diversified organic manures for regular supply of all type of nutrients. Organic manures act as food for microorganisms.

Benefits

- It creates vigorous crop growth with 4–5 times increase in tillers.
- Branching of culm is also higher than conventional process.
- It improves panicle length, number of fingers as well as test weight of finger millet grains.
- Soil health is improved through organic manuring, tillage and weed control.
- It ensures better weed control due to wider spacing of crop. Intercultural operations help in improvement of root system.
- It increases root volume and biomass for facilitation of nutrients and water uptake, resulting in yield improvement.
- It prolongs the crop maturity leading to high vegetative growth and reproductive organ development.
- It makes the crop to resist lodging, pest and disease attacks and to cope up with climate change.

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SUSTAINABLE AGRICULTURE THROUGH INTEGRATED FARMING SYSTEM (IFS)

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Abstract

Integrated farming system (IFS) is a mix of farm enterprises such as crop, livestock, aquaculture, poultry, sericulture and agro-forestry to achieve economic and sustained agricultural production through efficient utilization of resources. The principle of IFS model is developed such as wastes generated from one component becomes an input for other system and hence there is efficient recycling of farm and animal wastes in the integrated system. There is increase in yield per unit area through intensification and diversification of crops. Apart from this IFS helps in controlling insect pests and diseases and weeds through natural cropping system management and there is less use of harmful agro-chemicals for farm production. IFS is recognized as a solution to the continuous increase of demand for food production, providing stability to the income and nutritional security particularly for the small and marginal farmers with limited resources.

Keywords: Sustainable agriculture; Components of IFS; bioenergy; Soil health; Employment generation; Farming system.

Introduction:

Integrated farming system (IFS) is an integrated approach towards sustainable agriculture in this modern era. It is the integration of various agricultural enterprises or practices such as crops, livestock, Poultry, fish, agroforestry, horticulture, vermicomposting, Mushroom cultivation and beekeeping, in a single farming system. IFS is considered as the efficient tool for enhancing the profitability of farming systems especially for small and marginal farmers. IFS include various components or enterprises. These enterprises not only increase the farmer's income but also increase employment generation of a family. The judicious integration of these

agricultural enterprises improves the socio-economic status of the farmers. The crop production component of IFS includes the cultivation of various economically important crops such as cereals, pulses, vegetables, fruits, and herbs. IFS can be considered as a potential approach for rural bio-entrepreneurship and also as an important tool to double the farmer's income in India. The main aim of integrated farming system is to optimize the use of resources, increase farm productivity, improve farm income, and promote environmental sustainability. The integration of various farming components creates synergies that enhance overall farm efficiency and resilience.

Objective

The purposes or objectives of the Integrated Farming System are:

- To formulate farming system models involving main and allied enterprises for different farming situations.
- To ensure optional utilization and conservation of available resources and effective recycling of agricultural waste or residues within system
- To raise overall profitability of farm household by complementing main/allied enterprises with other.
- Enhances the productivity per unit area.
- Soil health management and soil conservation
- Generation of diversified income round the year and provide steady and stable income rejuvenation.
- Less use of chemicals.
- Increasing the yield of all integrated components and food security.

Components of Integrated Farming System

The strength of IFS lies in its ability to interlink multiple agricultural and allied enterprises, maximizing output and sustainability. Key components include:

1. Crop Cultivation

Cereals, pulses, oilseeds, vegetables, fruits, and herbs are grown in a coordinated manner. Practices like crop rotation, intercropping, mulching, and organic amendments maintain soil health, suppress pests, and diversify income sources. Crop residues can also be repurposed as fodder or compost.

2. Livestock Rearing

Cattle, goats, poultry, pigs, and other animals serve dual roles: income generation and nutrient cycling. Their manure acts as an organic fertilizer, enhancing soil fertility, while leftover crop biomass serves as animal feed.

3. Aquaculture

Fish ponds utilize nutrient-rich water from livestock shelters, and fish waste can fertilize crops. Integrating aquaculture enhances food diversity and system productivity.

4. Horticulture and Agroforestry

Fruit trees, timber species, and medicinal plants diversify farm income, prevent soil erosion, and enhance microclimates. Agroforestry systems also contribute to carbon sequestration and biodiversity.

5. Mushroom Cultivation

An efficient income-generating activity requiring minimal space and investment. Agricultural residues like straw are substrates for mushroom growth, turning waste into wealth.

6. Vermicomposting and Waste Recycling

IFS thrives on internal resource recycling. Earthworms decompose farm waste into nutrient-rich vermicompost, reducing dependency on chemical fertilizers.

7. Beekeeping (Apiculture)

Bees enhance crop yields through pollination while producing honey and beeswax valuable income sources with minimal input.

Figure 1: Components of IFS

8. Bioenergy Production

Bio-digesters convert animal waste into biogas for cooking and electricity, reducing fossil fuel reliance and enhancing farm self-sufficiency.

9. Water Management

Rainwater harvesting, drip irrigation, and wastewater reuse ensure efficient use of water a critical resource in agriculture.

Sustainability Impact and Benefits

IFS delivers comprehensive ecological and economic benefits. Its sustainability credentials are reinforced through impact studies comparing IFS with conventional systems:

Enhanced Productivity and Profitability

IFS increases per-unit productivity by efficiently utilizing every farm component. Diversified outputs like milk, eggs, vegetables, and fish ensure steady income throughout the year.

Soil and Water Conservation

The use of organic manure, mulching, and agroforestry improves soil structure and microbial activity. Fish and ducks, when integrated in rice paddies, churn the soil and reduce compaction, improving nutrient availability and water infiltration.

Greenhouse Gas (GHG) Mitigation

Rice-fish-duck farming has been shown to reduce methane and nitrous oxide emissions. Reduced chemical use and soil aeration from fish activity are key factors. Studies found that rice-fish-duck systems can reduce GHG emissions by over 12% compared to monoculture systems.

Nutrient Recycling

Animal manure, crop residues, and pond silt are continuously recycled into the soil, improving organic carbon levels and reducing dependency on synthetic inputs.

Employment and Livelihoods

IFS provides year-round employment, reduces rural-urban migration, and enhances food and nutritional security by diversifying farm outputs.

Risk Management and Resilience

By diversifying crops and enterprises, IFS reduces the risk of complete crop failure due to pests, market shocks, or climate variability.

IFS Models for Field Application:

Several successful models demonstrate the versatility of IFS in different agro-climatic zones.

Model 1: Horticulture + Piggery + Fisheries + Plantation Crops

- Pig dung is used as pond fertilizer.
- Fish ponds are shaded by plantation trees.
- Wastewater from piggery is reused for pond cleaning and irrigation.

Model 2: Agriculture + Horticulture + Poultry + Fishery + Mushroom

- Straw and poultry manure are used to grow mushrooms.
- Fish waste fertilizes fields.
- Diverse income from eggs, meat, mushrooms, and produce.

Challenges and Future Directions:

Despite its benefits, IFS adoption faces challenges, including:

- Lack of awareness and technical knowledge among farmers.
- Limited access to start-up capital and credit.
- Need for region-specific IFS models based on agro-ecological conditions.
- Inadequate marketing infrastructure for diversified farm produce.

Recommendations:

- **Field-based Demonstrations**: Practical IFS modules must be demonstrated on farmer fields to build confidence.
- **Policy Support**: Subsidies for bio-digesters, vermicompost units, and water harvesting structures should be provided.
- **Training and Capacity Building**: Farmers need technical training in managing multi-enterprise farms.
- **Research and Development**: More location-specific, scalable IFS modules need to be developed and tested.

Conclusion

The Integrated Farming System is not just a farming technique but a comprehensive livelihood strategy. It aligns with the goals of sustainable agriculture by promoting resource efficiency, minimizing environmental impact, and securing diversified income sources. As the Indian agricultural sector gears up to face the dual challenges of climate change and income insecurity, IFS offers a resilient, profitable, and sustainable pathway forward. Empowering farmers with knowledge, infrastructure, and institutional support to adopt IFS will not only double their income but also ensure food, nutritional, and ecological security for future generations.

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THE ROLE OF FISHERIES IN INDIA'S ECONOMIC DEVELOPMENT

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Abstract

In addition to providing jobs, raw resources, food security, capital formation, and national income, the fishing sector is a major contributor to India's economy. India generates 7% of agricultural Gross Value Added (GVA) and 8% of global fish output, ranking second in aquaculture and third in fish production worldwide. The sector's GVA grew steadily from ₹76,487 crore in 2013–14 to ₹1,47,518.87 crore in 2021–22, with an average annual growth rate of 8.61%. Government initiatives like the Pradhan Mantri Matsya Sampada Yojana (PMMSY), which aims to create 5.5 million employments by 2024–2025, highlight the importance of fisheries in job creation. In addition to economic benefits, fisheries provide essential raw materials for biotechnology, medicine, cosmetics, and food processing. Food security is also improved by the industry, which supports more than 28 million livelihoods and rising fish consumption per person. Fisheries also contribute to capital formation through economic diversification, infrastructural investment, and foreign exchange revenues. Modernization and sustainable management are still essential for maintaining long-term environmental and economic stability.

Keywords: Fisheries sector, India economy, Aquaculture, Fish production, Gross Value Added (GVA), Sustainable management, Modernization

Introduction

Employment, foreign exchange earnings, and food security all depend on the fishing sector, which is a key part of India's economy. About 7% of the country's agricultural Gross

Value Added (GVA) and 8% of the world's fish output come from India, the second-largest aquaculture nation and third-largest fish producer in the world. (Ministry of Fisheries, Animal Husbandry & Dairying, GOI, 2023). The export component of India's fisheries is similarly impressive. In fiscal year 2023–2024, seafood exports reached a record high of ₹60,523.89 crore. (MPEDA, Press Release: export performance 2023-24) Over the past ten years, shrimp exports alone have more than quadrupled to ₹40,013.54 crore. (MPEDA, Export Performance 2023-24) The fishing sector is vital to India's economic development and a significant source of jobs, export earnings, and national wealth. It must be continuously upgraded and expanded in order to achieve both long-term economic growth and food security.

Contribution of Fisheries to National Income

In the fiscal year 2021–2022, the fisheries industry contributed around 6.86% of India's agricultural GVA and 1.07% of its overall GVA. (GOI, 2025, Ministry of Finance). An all-time high of 161.87 lakh tons of fish were produced in India in 2021–2022. (GOI, 2023; Ministry of Fisheries, Animal Husbandry & Dairy). India is the world's second-largest producer of fish, accounting for 7.56% of global fish production. (India budget – Economic survey 2021-22)

Contribution of Fisheries to Employment.

Over time, there has been a significant rise in fish productivity. Government initiatives like the Pradhan Mantri Matsya Sampada Yojana (PMMSY) aim to greatly expand the sector's potential by creating 5.5 million employments by 2024–2025. (Department of fisheries, GOI). The primary objectives of these initiatives are to modernize infrastructure, promote sustainable practices, and provide loan assistance to fishermen and fish farmers.

Contribution of Fisheries as Supplier of Raw Material

Food Processing Industry

Fisheries provide the raw ingredients for many culinary items. The seafood industry produces dried, canned, frozen, and fresh products by processing fish, shellfish, and other aquatic animals. Small pelagic fish, such as sardines and anchovies, provide fishmeal and fish oil, which are vital ingredients in animal feed, aquaculture feed, and even human nutritional supplements.

Pharmaceutical and Nutraceutical Industry

For the pharmaceutical industry, fisheries constitute a significant source of bioactive compounds having medicinal properties. Omega-3 fatty acids, which are used in dietary supplements to support cardiovascular health, are frequently found in fish oil (*Kris-Etherton, P.*

M., Harris, W. S., & Appel, L. J. (2002). Marine drug development like spongothymidine and spongouridine from the Caribbean sponge *Tethya crypta* in 1950s (Bergmann and Feeney, 1951; Newman and Cragg, 2016). Natural bioactive compounds from marine organisms are being the functional ingredients to various health benefits (Atef, and Ojagh, 2017) and marine bacteria used as a source of metabolites (Alamgir et al. 2018). Additionally, marine life provides the basic materials needed to make drugs including antibiotics, anti-inflammatory drugs, and anti-cancer drugs.

Cosmetics and Skincare Industry

Marine-derived chemicals like Natural Calcium Phosphates (CaPs) Astaxanthin (*Siahaan, E. A., Agusman, Pangestuti, R., Shin, K. H., & Kim, S. K. 2022)* are increasingly being used in skincare and cosmetic products. Fish collagen, which is taken from the scales and skin of fish, is a major component in anti-aging creams and cosmetics. Seaweed and marine algae extracts are frequently utilized as natural moisturizers and antioxidants in skincare products.

Animal Feed and Agriculture

Fishmeal and fish oil are essential components in the feed business.

Fish meal is obtained by grinding the dried unwanted fish pieces *(Afreen, M., & Ucak, I. 2020).*These items are used to enhance the development and nutrition of cattle, poultry, and aquaculture species.

Marine waste is used as agricultural fertilizers and soil improvers (*González-Gaya et al., 2022).* Using fish-based feed boosts agricultural sustainability and productivity, supporting global food production systems.

Industrial and Biotechnological Applications

Numerous industrial operations employ raw resources from fisheries. Chitin and chitosan, (*Kumari et al.,2015).* which are extracted from shrimp and crab shells, are used in water purification, wound healing, and biodegradable packaging *(Lionetto and Corcione 2021).* Additionally, research is being done to promote sustainable energy sources by producing biofuel from fish waste (*Yuvaraj et al., 2019).*

Contribution of Fisheries in Food Security

In India, the fisheries sector is crucial to preserving food security and raising the per capita consumption of fish. India accounted for 7.96% of global fish production, making it the world's second-largest producer with an anticipated output of 14.73 million metric tons in 2020–

21. (IBEF, 2022). In 2022–2023, the country's per capita consumption of fish was 13 kg, a significant increase over previous years but still below the global average of 20.5 kg in 2019–20. (FAO, 2024). One of the government's initiatives to bridge this gap is the Pradhan Mantri Matsya Sampada Yojana (PMMSY), which seeks to boost fish production and consumption through improved market connections, policy assistance, and technology integration.

Contribution of Fisheries to Capital Formation

Fisheries are vital to capital growth because they provide profit, jobs, and foreign exchange. A key sector of many coastal and inland economies, fishing increases GDP by supplying food, raw materials, and trading opportunities. Investing in new fishing technique, aquaculture, and processing facilities boosts output and profitability, which encourages capital accumulation. Additionally, by boosting other industries like logistics, boat building, and cold storage, fisheries support economic growth. Governments and financial institutions assist the sector through subsidies, credit facilities, and infrastructure development, all of which boost capital creation. According to the Food and Agriculture Organization (FAO), sustainable fisheries significantly improve economic resilience by ensuring long-term resource availability and financial stability for fishing communities. Thus, good fisheries management and investment may boost capital formation and national wealth, fostering overall economic growth.

Conclusion

An important pillar of the Indian economy, the fishing industry makes a substantial contribution to capital development, employment, national revenue, and food security. India, the world's second-largest aquaculture producer and third-largest fish producer, has seen impressive increase in both fish output and exports. In addition to providing vital raw materials for sectors including food processing, medicines, cosmetics, and biotechnology, the industry sustains the livelihoods of millions of people. Modernization, sustainability, and economic resilience are still being promoted by government programs such as the Pradhan Mantri Matsya Sampada Yojana (PMMSY). However, maintaining long-term growth, environmental balance, and global competitiveness still depends on infrastructural development and sustainable fisheries management.

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ENHANCING NUTRITION THROUGH BIOFORTIFICATION: A PATH TO HEALTHIER CROPS

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Abstract

Malnutrition, particularly in the form of "hidden hunger," remains a pressing global health issue affecting millions, especially in underdeveloped regions. Despite sufficient caloric intake, many individuals suffer from deficiencies in essential micronutrients. Biofortification has emerged as a promising, cost-effective, and sustainable solution to address these nutritional gaps by enhancing the nutrient content of staple crops. This paper explores the history, approaches, and advancements in biofortification including agronomic, conventional breeding, transgenic, genetic, and nanotechnological methods. Each approach offers unique benefits, such as improved crop yields, enhanced resistance to environmental stresses, and increased availability of key nutrients like iron, zinc, and vitamin A. However, challenges such as high production costs, potential environmental impacts, limited accessibility, and concerns over genetic modification remain significant barriers. By integrating biofortification with broader strategies like dietary diversification and policy support, global efforts can be strengthened to combat malnutrition. Ultimately, biofortification represents a vital component of the solution to ensuring food and nutrition security for present and future generations.

Keywords: Malnutrition, Hidden hunger, Food security

Introduction

Malnutrition poses a significant challenge across the globe, negatively impacting the health and development of large populations. The term “hidden hunger” illustrates that people may consume enough food in quantity but still miss out on vital nutrients, leading to both undernutrition and overnutrition (Ofori *et al*., 2022). The number of individuals suffering from hidden hunger reached 828 million in 2021, an increase of approximately 46 million from 2020 and 150 million more since the beginning of the COVID-19 pandemic (WHO, 2022). Economic disruptions, such as those caused by COVID-19, limit people's access to nutritious food. During such hardships, many restrict to cheaper, less nutrient rich staples like rice, which satisfies the carbohydrate requirement alone (Shahzad *et al*., 2023). This behavior contributes to the growing issue of hidden hunger, not due to the absence of healthy foods, but because they are often not selected. It is vital to address the diverse consequences of malnutrition and understand its connection to broader global challenges. Achieving widespread success also requires addressing regulatory challenges, enhancing consumer acceptance, and minimizing environmental impacts—all of which demand rigorous testing and collaborative efforts (Vachon & Klassen, 2006, 2008). In the broader fight against malnutrition, genetic biofortification stands out as a promising and integrative strategy, especially when combined with dietary diversification and other complementary approaches to improve crop nutrition and strengthen community health (Msungu *et al*., 2022; Schnurr, 2019).

History of biofortification

Biofortification as a concept emerged during the Green Revolution era (1966–1985) (Pingali, 2012). In the early 1990s, American economist Howarth E Howdy Bouis initiated efforts to tackle the problem of micronutrient malnutrition. Primarily, nutrition experts focused mainly on calorie intake as the standard for assessing nutritional health. However, research conducted by Howarth Bouis and Lawrence Haddad between 1984 and 1990 highlighted that the major barrier to improved nutrition and the reduction of micronutrient deficiencies was inadequate intake of essential minerals and vitamins. In 2001, Steve Beebe introduced the term biofortification. Biofortification Challenge Program established by CGIAR in 2003 was renamed HarvestPlus. HarvestPlus nutrition and crop specialists collaborate with CGIAR partners to create staple crop

varieties enriched with micronutrients that can significantly improve human health and nutrition, fulfil farmers' agricultural requirements, and be well-received by consumers.

Biofortification involves increasing the concentration of essential micronutrients in crops by modifying the biological pathways that influence nutrient uptake and distribution. It is widely recognized by researchers and policymakers as a more efficient solution than traditional methods like dietary supplements, food diversity, or conventional fortification (Hotz *et al*., 2012; Avnee *et al*., 2023). This approach is not only cost-effective but also practical for widespread implementation.

Malnutrition: a hidden hunger

Across the globe, malnutrition continues to quietly impact lives in the form of "hidden hunger," an invisible yet pervasive issue (Modak 2020). This condition undermines the well-being of communities, leading to poor health, restricted development, and persistent poverty. Although traditional concerns centered on chronic undernutrition, the rise of obesity has emerged as a major global health challenge (Jannuzzi *et al*. 2022). This combination reveals the intricate nature of malnutrition (Biswas *et al*. 2021). Hidden hunger results in impaired physical growth, delayed cognitive development, weakened immune function, and a higher risk of chronic and degenerative diseases later in life (Ibeanu *et al*. 2020). As malnutrition involves insufficient intake of key nutrients such as proteins, fats, carbohydrates, vitamins, and minerals (Sharma *et al*. 2023), inadequate nutrient consumption can lead to developmental delays, reduced immune defenses, and cognitive impairments (Mehta *et al*. 2013).

Fig 1: Approaches of biofortification

While excessive calorie intake can contribute to obesity and metabolic disorders like diabetes (Hawley *et al*. 2020). Hidden hunger occurs when individuals consume enough or even excess calories but lack the essential nutrients their bodies need. Diets primarily composed of staple foods with little variety tend to worsen this form of malnutrition (Burchi *et al*. 2011).

Plant science-based approach for biofortification

There are various modern plant science base approach use for development of biofortified crops (Fig. 1). The primary aim of biofortification is to ensure the production of food that is both nutritious and safe, while also being sufficient and environmentally sustainable (Saltzman, 2013).

There are three key methods to achieve biofortification in crops:

1. **Transgenic approach** – involving the application of **biotechnology**,
2. **Conventional breeding** – using **traditional crop improvement techniques**, and
3. **Agronomic approach** – through the use of **fertilizers and soil management practices**

Agronomic approach

Agronomic biofortification can improve both crop growth and the efficiency with which plants absorb and utilize micronutrients (Zulfqar *et al*. 2020b, 2021b). Various strategies such as soil amendments, foliar sprays, and seed treatments can be employed to address micronutrient deficiencies (Rehman *et al*. 2020). While agronomic biofortification is generally a straightforward and cost-efficient method, its success depends on careful selection of nutrient sources, appropriate application techniques, and awareness of potential environmental effects. By modifying soil properties, this approach has shown promise in improving crop nutrition (Zulfqar *et al*. 2021) particularly in enhancing the zinc (Zn) content of essential crops like wheat and rice. Micronutrients such as iron (Fe), zinc (Zn), copper (Cu), magnesium (Mg), iodine (I), selenium (Se), molybdenum (Mo), cobalt (Co), and nickel (Ni) are present in varying concentrations throughout different parts of the plants and are typically absorbed from the soil. Enhancing the soil's micronutrient content through agronomic practices can temporarily boost the nutritional quality of crops and play a role in reducing micronutrient deficiencies in human population (Cakmak, 2008). These practices generally involve the direct application of mineral-based fertilizers (Cakmak and Kutman, 2018) and the promotion of nutrient mobilization and solubilization from soil to the edible portions of the plants. Compared to their inorganic counterparts, organic forms of minerals are more bioavailable, as they are more readily absorbed,

excreted less, and present fewer toxic effects (Daniels, 1996; DRI, 2000). For instance, using selenium-complex salts as fertilizers can lead to the production of selenium enriched soybeans (Yang, 2003).

Conventional breeding approach

Conventional breeding is the most widely accepted method of biofortification, as it offers a sustainable and cost effective alternative to transgenic and agronomic approaches. To make this method feasible, it is essential to first screen germplasm to ensure adequate genetic diversity. Pre-breeding of parental genotypes is required to enhance the effectiveness of conventional breeding. During the selection of parental lines, important agronomic and plant-type traits are evaluated. If the desired variability is found in unadapted genetic resources (strategic gene pool), pre-breeding becomes necessary before incorporating the trait. However, if the variability exists in adapted germplasm, it can be directly used to develop new crop varieties. In this biofortification strategy, nutrient-rich parent lines are repeatedly crossed with recipient lines that possess favorable agronomic characteristics. Over multiple generations, this results in new lines that combine both improved nutrient content and desirable agronomic traits. The use of molecular markers significantly reduces costs and accelerates the breeding process. Once promising lines are developed, they are evaluated across various locations and environmental conditions to assess genotype by environment (G x E) interactions. The most promising varieties from this testing are selected for further multilocational and multi-seasonal trials conducted by national research partners. Successful candidates are then submitted to government agencies for official agronomic performance evaluation and eventual release.

Transgenic approach

The transgenic approach is most effective when the desired nutrient is either absent or present at insufficient levels in available germplasm collections, indicating limited or no genetic variability (Zhu *et al*., 2007; Brinch-Pedersen *et al*., 2007). The foundation of developing transgenic crops lies in the ability to identify, understand, and utilize specific genes to modify plant metabolic pathways (Christou and Twyman, 2004). This method benefits from access to an unrestricted genetic pool, allowing for the transfer and expression of beneficial genes across different plant and animal species, regardless of their evolutionary or taxonomic relationships (Pérez-Massot *et al*., 2007). Moreover, genes and metabolic pathways from bacteria and other non-plant organisms can be incorporated through metabolic engineering techniques (Newell-

McGloughlin, 2008). Although the initial development of transgenically enhanced crops requires considerable time and financial investment, they are proved to be economical over the long term (Hefferon, 2016; Guo, 2005). An additional advantage of this approach is its freedom from taxonomic boundaries, as it also allows the use of synthetic genes. Genetic biofortification, a strategic method that uses crop genetics offers a promising solution to combat hidden hunger (Kudapa *et al*., 2023). It enhances key nutrients such as iron, zinc, and vitamin A in staple foods (Kumar *et al*., 2019). This approach has the potential to revolutionize nutrition, particularly in underdeveloped regions heavily affected by hidden hunger. There are numerous genetically modified crops currently available that demonstrate improved levels of essential micronutrients.

Table 1. Biofortified genetically modified crops

Crop	Micronutrient Enhanced	Method	Micronutrient Benefit	Example/Variety
Golden Rice	Vitamin A (β-carotene)	Genetic modification	Helps prevent Vitamin A deficiency (VAD)	Golden Rice (GR2E)
Iron-rich Rice	Iron, Zinc	Genetic modification	Improves iron and zinc content for anaemia prevention	Ferritin-expressing rice
Iron-rich Wheat	Iron	Genetic modification	Higher iron bioavailability	NA (in trials)
Zinc Wheat	Zinc	Conventional breeding	Improves immune function and growth	WB02, HPBW01 (India)
Iron-rich Pearl Millet	Iron	Conventional breeding	Prevents iron deficiency in dryland areas	Dhanashakti (India)
Pro-vitamin A Maize	Vitamin A (β-carotene)	Conventional breeding	Reduces childhood blindness	Orange Maize (HarvestPlus)
Iron-rich Beans	Iron	Conventional breeding	Enhances dietary iron intake	Manteca, Ervilha (Africa)
Zinc Rice	Zinc	Conventional	Fights stunted growth	BRRI dhan-62

		breeding		(Bangladesh)
Biofortified Cassava	Vitamin A, Iron, Zinc	Genetic modification	Improves multiple micronutrients in root crops	Transgenic cassava (in R&D)
Sweet Potato (Orange-Fleshed)	Vitamin A	Conventional breeding	High β-carotene content	Kabode, SPK004 (Africa)

Nano technological approach

In the 21st century, nanotechnology has emerged as a ground breaking tool in the field of agriculture. It holds significant promise for addressing various agricultural challenges and ensuring food security, particularly in combating malnutrition. One notable application is nanotechnological biofortification, where nano fertilizers are utilized (Rajput *et al*., 2018). Due to their high surface area to volume ratio, nano fertilizers are more effective compared to traditional fertilizers. Unlike conventional ones, nano fertilizers are quickly absorbed by plants and do not accumulate in the soil, thereby improving the nutritional quality of biofortified crops. Nano fertilizers are efficiently absorbed by plants and do not accumulate in the soil, leading to improved nutritional value in biofortified plant products. These fertilizers include materials such as zinc oxide nanoparticles (ZnONPs), silica, iron and titanium dioxide, ZnS/ZnCdSe core-shell quantum dots (QDs), InP/ZnS QDs, Mn/ZnSe QDs, gold nanorods, aluminium oxide (Al_2O_3), titanium dioxide (TiO_2), cerium dioxide (CeO_2), and iron oxide (FeO). These nanomaterials act as multi-nutrient boosters for plant growth. The effectiveness of nano fertilizers depends on factors like particle size, concentration, composition, chemical nature of the nanomaterial, and the type of plant species. Advancements in nano-agriculture require a strong understanding of biology, biotechnology, materials science, and engineering, as the integration of these fields offers new technologies to help address 'hidden hunger' through improved crop nutrition.

Advantage of biofortification

Minerals enhance the agronomic performance of plants, leading to improved yields, greater resistance to pests, and better tolerance to environmental stress. As a result, biofortified crops can thrive even in mineral deficient soils and support increased productivity. These crops offer

elevated levels of essential nutrients such as beta-carotene, zinc, iron, vitamin D, tryptophan, and lysine. Once biofortified crop varieties are developed and widely adopted, they can be cultivated and consumed repeatedly over the years, offering long-term nutritional benefits. Farmers can access biofortified seeds at the same price as traditional varieties, making it a highly cost-effective approach. Since biofortification targets staple foods that are already part of the daily diet of low-income populations, these crops can be easily incorporated into their eating habits, potentially contributing to poverty reduction. Biofortified crops are capable of reaching marginalized and remote populations, ensuring that the most vulnerable groups benefit from improved nutrition.

Disadvantages of biofortification

The production of biofortified rice is costly due to advanced technologies and patenting requirements. It may pose ecological risks by impacting nearby non-GM or wild rice varieties and often provides lower nutritional value compared to conventional supplements. Limited accessibility in poor rural areas, coupled with potential health concerns such as allergic reactions from genetic modifications, further challenges its widespread adoption.

Conclusion

The rising global population and intensifying greenhouse effect, coupled with declining crop quality, have negatively impacted essential factors such as nutrient and protein levels. As a result, there is an urgent need for effective solutions that can enhance both the quantity and quality of crops to ensure food security for all people across the globe. One promising approach is the development of biofortified crops, achieved through either traditional breeding techniques or advanced biotechnological innovations, which pose no risk to human health. Ultimately, the primary goal in addressing global nutrition challenges is to provide a sufficient, nutritious, and varied diet for the entire human population.

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BOTANICAL DESCRIPTION AND ECONOMIC IMPORTANCE OF GINGER (*ZINGIBERA OFFICINALE*)

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Introduction

Ginger (Zingibera officinale) is a flowering plant whose rhizome, ginger root or ginger, is widely used as a spice and a folk medicine.Ginger is an herbaceous perennial which grows annual pseudostems about one meter tall bearing narrow leaf blades. The inflorescences bear pale yellow with purple flowers and arise directly from the rhizome on separate shoots. Some of the basic types of ginger are baby ginger, blue Hawaiian ginger, white ginger, yellow ginger, alpinia ginger, beehive ginger, butterfly lily ginger, dancing ladies ginger, globba ginger, hidden ginger, moth ginger, red ginger, shell ginger, spiral ginger, torch ginger, zingiber ginger. Ginger is consumed worldwide as a spice and for its therapeutic properties. The plant has a number of chemicals responsible for its various medicinal properties, such as antiarthritis, antiinflammatory, antidiabetic, antibacterial, antifungal, anticancer effects, etc.

The total production of ginger in the world is 1,683 thousand tons with the total acreage of 310 thousand ha. China, India, Nepal and Thailand are the major producers of ginger in the world, having production of 396.60 thousand tons, 385.33 thousand tons, 210.79 thousand tons and 172.68 thousand tons respectively. India holds the seventh position in ginger export worldwide, however is the "largest producer of ginger in the world". Raw ginger is composed of 79% water, 18% carbohydrates, 2% protein and 1% fats. The characteristics fragrance and flavour of ginger result from volatile oils that compose 1-3% of the weight of fresh ginger,

primarily consisting of zingerone, shogaols and gingerols with 6-gingerol as the major pungent compound. Ginger can be used for a variety of food or medicine items such as vegetables, candy, soda, pickles and alcoholic beverages.

Common name	:	Ginger (English), Ingee (Tamil), Adrak (Hindi).
Scientific name	:	*Zingibera officinale*
Family	:	Zingiberaceae
Wild species	:	Asarumcanadense
Chromosome number	:	2n=22
Origin of the crop	:	Southeast Asia.
Distribution of the crop	:	Pacific island, Hawaii, South India, Sri Lanka
Habit	:	Perennial, aromatic herb.
Habitat	:	Humid partly-shaded habitats in moist tropical and subtropical forests of Southeast Asia.
Root system	:	Adventitious, rarely fibrous.
Stem	:	Rhizome-tuberous, aerial, braked, scapose or leafy, short or elongated. In curcuma the aerial system is very short or even absent; sometimes formed by the rolled-up leaf sheaths.
Leaf	:	Radicle or cauline, exstipulate; petiolate or sessile; leaf base sheathing in some (curcuma); entire; elliptical or linear or lanceolate; apex acute or obtuse; parallel unicostate.
Flower	:	Bracteate; pedicellate or sessile; complete: zygmorphic; irregular; bisexual; epigynous; cyclic; calyx and corolla are distinct; flowers usually large in size and brightly coloured, aromatic, except in costus, monocostus, dimerocostus and tapeinocostus.

Calyx	:	Sepals 3; gamosepalous; tubular or spathe like; generally3-thoothed; green; superior. In globba the calyx tube is very short; odd sepal anterior.
Corolla	:	Petals 3; free or less united; tubular or funnel-shaped; three-lobed,lobes unequal; linear or broad. In Roscoea the corolla tube is longand slender with upper lobe broad, cucculate, and erect, the two lateral lobes spreading and narrower. Corolla tube longer than the calyx tube.
Androecium	:	Stamens six, arranged in two whorls, the posterior stamen or the inner whorl is fertile and epipetalous and antipetalous, the other two stamens of the inner whorl are sterile and mostly petloid and are fused together to form the petaloid lip or labellum, which may be two or three lobed. The anterior stamen of the outer whorl is always absent, the other two may be absent (Renealmia) or may be present as large leafy staminodes right and left of the fertile stamen. In Curcuma, Roscoea and Zingiberthe anther lobes are joined by a long-spurred connective, the spurs standing above the lip; in Roscoeathe connective has two basal spurs.
Gynoecium	:	Tricarpellary, syncarpous, inferior, trilocular with axile placentation. ovules many and superposed in each loculus. The ovary is unilocular with parietal placentation. In monocostus the ovary is bilocular with parietal placentation (third loculus is suppressed). In Haplochorema the ovary is unilocular with a few basal ovules. Ovules are usually anatropous or semi-

		anatropous. Style one, simple, usually slender, stigma simple and capitate or three lobed.
Fruit	:	Loculicidal capsule, opening by three valves.
Seed	:	Endospermic.
Floral formula	:	%,♂,$K_{(3)},C_{(3)},A_1,G\overline{(3)}_{or}\overline{(2)}$
Pollination	:	Entomophilous.

Economic importance:

- The commercial ginger is prepared from the aromatic creeping, thick, jointed branching root-stocks of *Zingiber officinale.*
- It is also used in the spice, cosmetic industry and is added to perfumes, lotions, and balms as a fragrance ingredient and skin-conditioning agent.
- It is used in many ayurvedic medicine.
- These are cultivated in gardens and green houses for decorative purpose.
- Used to help digestion and treat stomach upset, diarrhea, and nausea for more than 2000 years.
- Ginger has also used to help treat arthritis, colic, and heart conditions.
- Ginger leaf tea is consumed for morning or motion sickness, colds, nausea, indigestion, and other ill feelings. The leaves also contain antibacterial and antifungal properties.

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BIOREMEDIATION OF OIL SPILLS

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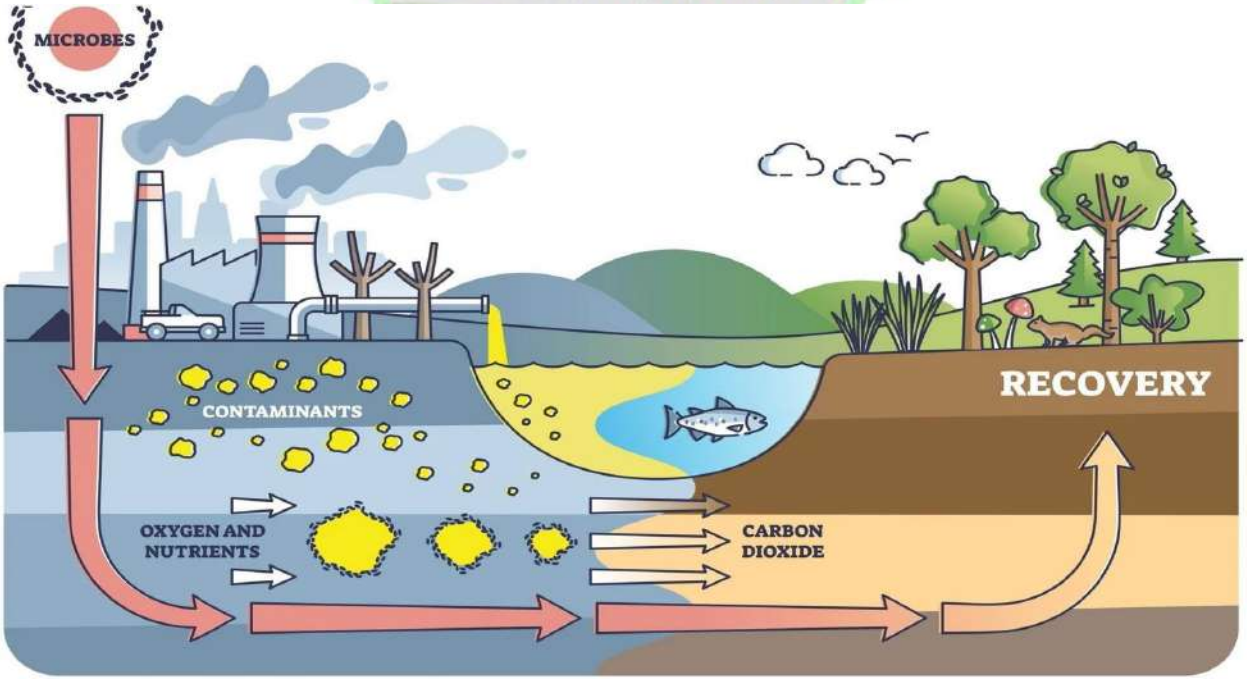
Introduction

Oil spills occur frequently throughout the world. There are both inland and oceanic spills. Oil spills require quick action so that they cause as little damage as possible.

According to the environmental protection Agency(EPA),"Oil releases threaten public health and safety by contaminating drinking water, causing fire and explosion hazards, diminishing air and water quality, compromising agriculture, destroying recreational areas, wasting non-renewable resources, and costing the economy millions of dollars". Bio remediation offers a promising approach to addressing this challenge.



The use of microorganisms, fungi or bacteria, to decompose pollutants into simpler compounds is called Bio remediation. Microbes breaking down different substances into water, carbon dioxide, and other compounds.

The prime goal of Bio remediation is to create an optimal environment for the microbes to degrade pollutants. Bio remediation is cost effective alternative but is a very slow process, sometimes taking weeks to months for results. An advantage of Bio remediation is that the microbes are able to completely destroy the toxic hydrocarbon compounds and do not just transfer them to another area. There are two primary strategies are used in oil spill bioremediation .Bio stimulation and bio augmentation.

Bio stimulation is a type of bioremediation strategy in which nutrients or other substances are added to a contaminated environment to stimulate the activity of the native (indigenous) microorganisms, encouraging them to degrade pollutants more effectively. By adding things like nitrogen, phosphorus, or oxygen-releasing compounds, we "feed" or "stimulate" these microbes so they multiply and work faster to clean up the contamination. Examples of substances used for stimulation are Fertilizers (for nutrients),Oxygen-releasing compounds (like hydrogen peroxide),Surfactants (to make pollutants more bioavailable).Bio stimulation is less expensive natural process which is not disruptive to surrounding ecosystem. It is a continuous process to Improve condition and does not require to moving oil to another location. But there are some disadvantages in bio stimulation such as takes time to evaluate site and see results and success depends on proper nutrients and environmental conditions.

Bio augmentation is the process of adding specific strains of microorganisms (bacteria, fungi, or other microbes) directly into a contaminated environment to enhance the degradation of pollutants. Sometimes the native microbes in the contaminated site aren't able to break down certain pollutants effectively (or at all).Scientists or engineers introduce specialized microbes known to degrade those specific contaminants. Examples of microbes used in bio augmentation includes *Pseudomonas putida* for breaking down aromatic hydrocarbons, *Dehalococcoides* species for chlorinated solvents. Here introduced microbes can efficiently degrade specific contaminants that native microbes can't handle. It can significantly reduce remediation time compared to relying on natural attenuation and it is effective for pollutants that are persistent or toxic (e.g., chlorinated solvents, hydrocarbons). Specific strains can be selected or engineered for particular contaminants. It is useful in soil, groundwater, sediments, and wastewater. It is an eco-

friendly alternative to harsh chemical remediation methods. But in bio augmentation Introduced microbes may fail to establish due to competition or predation and factors like pH, temperature, moisture, and nutrient availability can also reduce effectiveness. Bio augmented microbes may not remain active long enough for complete remediation. Culturing, transporting, and applying microbes can be expensive. Risk of disrupting native ecosystems or introducing nonnative species. Laboratory success doesn't always translate to real-world effectiveness due to complex site conditions.

Key microorganisms in oil spill bioremediation are Marine and coastal oil-degrading bacteria (*hydrocarbonoclastic* bacteria)- These microbes specialize in breaking down hydrocarbons (the main components of oil) and thrive in oil-contaminated waters and sediments .

Alcanivorax borkumensis -One of the most important marine bacteria in oil spill clean up. Dominates in the presence of oil when nitrogen and phosphorus nutrients are available (bio stimulation).Degrades straight-chain alkanes.

Cycloclasticus spp.-Specialize in polycyclic aromatic hydrocarbons (PAHs) — some of the most toxic and persistent oil components.

Marinobacter spp. -Versatile marine oil degraders that break down both alkanes and aromatics.

Oleispira antarctica- Psychrophilic (cold-loving) bacterium active in cold marine environments — ideal for oil spills in polar or sub polar regions.

Generalist soil and water bacteria -These microbes can act in both marine and terrestrial spills:

Pseudomonas spp. -Produce biosurfactants (natural detergents) that help emulsify oil droplets, increasing oil's bioavailability.

Degrade a wide variety of hydrocarbons.

Rhodococcus spp.-Excellent at degrading complex, branched hydrocarbons; tolerate harsh conditions.

Sphingomonas spp. -Effective at degrading persistent and toxic PAHs.

Fungi (especially white-rot fungi)

Phanerochaete chrysosporium and related fungi -Produce powerful oxidative enzymes (lignin peroxidase, manganese peroxidase, laccase) that break down complex hydrocarbons, including recalcitrant components like asphaltenes. There are so many oil spills Incidents in the history such as the Exxon Valdez oil spill in the year 1989, the Amoco Cadiz Oil Spill in 1978, the Castillo de Bellver Oil Spill in 1983,the Incidents at the Nowruz Oil Field in 1983, the Kolva

River Spill in 1994, the Mingbulak (or Fergana Valley) Oil Spill in 1992,the Atlantic Empress Oil Spill in 1979, the Ixtoc 1 Oil Spill in 1979, BP's Deepwater Horizon Oil Spill in 2010 ,the Persian Gulf War Oil Spill in 1991.

After the Exxon Valdez oil spill, adding nitrogen and phosphorus fertilizers to beaches (bio stimulation) greatly increased populations of native oil-degrading bacteria (like Alcanivorax), speeding up oil breakdown.

Pseudomonas putida was the main microorganisms used for removing oil spills incident occurred off the coast of Kochi, Kerala, India, on May 25, 2025, when a container vessel, the MSC ELSA 3, capsized and leaked fuel into the Arabian Sea.

There so many Limitations and challenges in bioremediation of oil spills includes it's effectiveness depends on environmental factors like temperature, salinity, oxygen levels, and nutrient availability. It is a slow process compared to physical removal in large, acute spills. Some oil components, like heavy asphaltenes, are resistant to microbial degradation.

Advancements in genetic engineering and microbial ecology are paving the way for developing super-efficient oil degrading bacteria. Combined with predictive models and real-time monitoring, these innovations could make bioremediation a faster and more reliable first-line response to oil spills.

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DR. B.R. AMBEDKAR: THE VISIONARY BEHIND INCLUSIVE RURAL TRANSFORMATION

Article ID: AG-V05-I08-52

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Abstract

Dr. B.R. Ambedkar, renowned as the principal architect of the Indian Constitution, was also a pioneering advocate of inclusive rural development. His visionary emphasis on education, land reform, social equity, and institutional empowerment laid the foundation for participatory governance and the upliftment of marginalized communities. This article explores the continuing relevance of Ambedkar's ideology in the modern context of rural and fisheries extension. From digital inclusion and targeted livelihood schemes to community-based institutions and caste-sensitive policy frameworks, the impact of Ambedkar's thought is evident across India's rural transformation agenda. His enduring legacy continues to inspire extension professionals working towards equity, empowerment, and sustainable development.

Keywords

Dr. B.R. Ambedkar, Inclusive Rural Development, Extension Education, Social Equity, Digital Inclusion, Marginalized Communities, Fisheries Extension, SHGs, SCSP, PMMSY, Institutional Empowerment

Introduction

Dr. Bhimrao Ramji Ambedkar (1891–1956) was not only the father of the Indian Constitution but also a reformer who laid the ideological groundwork for inclusive and participatory development. He was a firm believer in equality, education, and social justice for the downtrodden. These values resonate with the principles of rural and fisheries extension, which seek to empower marginalized communities through access to information, education, and

technology (Deshpande, 2011). In the present era, where digital transformation and climate resilience dominate development discourse, Ambedkar's vision of an inclusive India is more relevant than ever (Kumar et al., 2022).

Figure1: Dr. B.R. Ambedkar standing among his followers during a public meeting, symbolizing his leadership in the movement for social justice and equality.

Education as the First Step to Empowerment

Dr. B.R. Ambedkar championed education as the most effective means to dismantle social inequality and empower the marginalized. His slogan "Educate, Agitate, Organize" articulates a transformative process: education builds awareness, agitation challenges injustice, and organization fosters collective action. This approach aligns closely with the core objectives of extension education, which aims to empower rural communities through knowledge dissemination, skill development, and participatory engagement. Today, Ambedkar's vision is reflected in initiatives like Krishi Vigyan Kendras (KVKs), which serve as grassroots knowledge hubs offering practical training and advisory services. Digital platforms like MatsyaSetu and online farmer field schools further democratize access to scientific information, especially for SC/ST farmers and rural women. These tools not only bridge the knowledge gap but also promote inclusive development—bringing Ambedkar's ideals to life in the modern extension landscape (Kumar et al., 2022).

Digital Inclusion and Social Equity

Dr. B.R. Ambedkar was far ahead of his time in championing equitable access to state resources for all citizens, particularly those who were marginalized. His vision of inclusive governance resonates strongly in today's efforts to empower rural communities digitally. Initiatives like Digital India, PM-WANI (Public Wi-Fi Access Network Interface), and Common Service Centres (CSCs) are modern tools that help bridge the rural-urban digital divide. These

platforms enable smallholder farmers and fishers to access government schemes, market information, financial services, and expert advisories—resources that were once out of reach for many. By democratizing access to information and opportunities, these digital initiatives reflect the spirit of Ambedkar's commitment to social justice and participatory development (Planning Commission, 2013; FAO, 2023).

Land and Livelihood Reforms for the Marginalized

Economic empowerment through land and livelihood security was central to Ambedkar's thinking. As Labour Minister in British India, he proposed land reforms and state-supported irrigation to aid small farmers and landless laborers. Today, this vision is reflected in schemes such as PM-KISAN, land record digitization efforts, and FPO promotion for SC/ST groups. In fisheries, programs under the Pradhan Mantri Matsya Sampada Yojana (PMMSY) are creating inclusive income opportunities, echoing Ambedkar's belief in economic justice for the poorest (Singh, 2015; DAHD, 2023).

Institution Building for Inclusive Governance

Dr. B.R. Ambedkar's legacy as a visionary institution builder is evident in the foundations of India's inclusive governance system. He played a key role in establishing institutions like the Reserve Bank of India and advocated for decentralized financial systems to uplift the rural poor. His foresight in creating structures that serve the marginalized continues to resonate today through grassroots institutions such as Self-Help Groups (SHGs), cooperatives, Farmer Producer Organizations (FPOs), and Panchayati Raj Institutions (PRIs). These bodies empower local communities—especially the underprivileged—to participate in decision-making, manage resources, and drive their own socio-economic development. In essence, they carry forward Ambedkar's vision of democratizing access, equity, and empowerment at the grassroots (Deshpande, 2011; Kumar et al., 2022).

Social Inclusion in Extension and Development

Dr. B.R. Ambedkar's unwavering advocacy for the dignity of labor and caste equity continues to influence inclusive development policies in India. Frameworks like the Scheduled Caste Sub-Plan (SCSP) and Tribal Sub-Plan (TSP) are designed to channel targeted resources to historically marginalized communities. In the realm of extension education, this vision is reflected through focused initiatives aimed at empowering SC/ST fishers, women, and other disadvantaged groups. Through capacity-building programs, financial inclusion,

entrepreneurship training, and access to technologies, extension systems strive to create equal opportunities. These efforts uphold Ambedkar's enduring commitment to building a socially just, equitable, and participatory society (Planning Commission, 2013; Singh et al., 2022).

Conclusions

Dr. B.R. Ambedkar envisioned an India where every citizen could live with dignity, regardless of caste, class, or gender. His influence continues to be felt in rural development and extension systems through education, equity-based schemes, participatory institutions, and digital inclusion. As India advances toward inclusive and sustainable rural development in 2024 and beyond, Ambedkar's values remain foundational. He was not only a constitutional architect but also a guiding force for today's extension professionals committed to empowering the last and the least (Ambedkar, 1946; Singh et al., 2022).

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GRAFTING TECHNIQUES TO MITIGATE ABIOTIC STRESS IN VEGETABLE CROPS

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Abstract

Grafting is an effective technique to enhance abiotic stress tolerance in vegetable crops by combining stress-resistant rootstocks with high-yielding scions. It improves water and nutrient uptake, confers resistance to salinity, drought, and temperature extremes, and ensures stable crop production. This eco-friendly approach reduces the dependence on chemical inputs and promotes sustainable agriculture.

Key words: Grafting, Abiotic stress, Vegetable crops, Rootstock, Drought tolerance, Salinity resistance, Sustainable Horticulture.

Introduction

Stress in plants refers to any unfavorable condition or substance that disrupts or hinders their normal metabolism, growth or development. Among the various types, **abiotic stress** is caused by adverse physical or chemical factors such as extreme temperatures, water scarcity or excess, high salinity, heavy metal toxicity and ultraviolet (UV) radiation. These stressors pose significant challenges to agriculture and ecosystems, leading to substantial reductions in crop yield. Among them, salt stress is particularly persistent and concerning due to the ongoing salinization of arable lands worldwide, which continues to intensify the problem.

Different types of grafting methods

1. Tongue / approach grafting

- Equal size of rootstock and scion are used for grafting.
- This method requires more labour and space but percentage of seedling survival is high

and most commonly practice by small nurseries farmers.

- This method is not used in rootstocks with hollow hypocotyls.

2. Cleft grafting

- It is also called apical or wedge grafting.
- In this method slant angle is made in lower stem and scion is pruned with 1-3 true leaves and scion is placed into split and clip is attach in between scion and rootstock. This is done in mainly Solanaceous crops.

3. Hole insertion

- This is also known as top insertion grafting This is mostly done in watermelon as the seedling size is smaller than the than rootstock of bottle gourd or squash.
- For transplanting optimum temperature required is 21-36℃.

4. Splice grafting

- This method is mostly used by growers.
- It can be practice by hand or machines in most Cucurbits and Solanaceous vegetable crops.

5. Pin grafting

- In this method designed pins are used to hold the grafted position instead of placing grafting clips. It is similar method as splice grafting.

Table 1: Grafting methods and rootstocks used in vegetable crops

Scion plant	Rootstock	Method
Cucumber	*Cucurbita moschata, Cucurbita maxima*	Tongue and top insertion method
Watermelon	*Benincasa hispida, Cucurbita moschata, Cucurbita melo, Cucurbita moschata* × *Cucurbita maxima , Lagenaria siceraria*	Top insertion and cleft method and slice grafting
Bitter gourd	*Cucurbita moschata , Lagenaria siceraria*	Top insertion and tongue method
Bottle gourd	*Cucurbita moschata, Luffa sp*	Top insertion and tongue method
Tomato	*Lycopersicum pimpinellifolium*	Cleft grafting

	Solanum nigrum	Tongue and cleft grafting
Brinjal	*Solanum torvum*	Tongue and cleft grafting
	Solanum sissymbrifolium	Cleft method
	Solanum khasianum	Tongue and cleft method

Basic requirement for vegetable grafting

The basic requirements for vegetable grafting include careful selection of the appropriate rootstock and scion, which is typically performed at the 2–3 true leaf stage, ensuring both have similar stem diameters for successful union. Graft compatibility is crucial as it minimizes mortality rates during later growth stages, with vascular bundle formation occurring due to callus development between the scion and rootstock. Various grafting aids such as clips, tubes, pins and grafting blades are used to facilitate the process. Seedlings are initially raised in a screening house made with 60-mesh nylon net prior to grafting. Post-grafting, the healing process is carried out in a healing chamber with a temperature of 28–29°C and about 95% relative humidity for 5–7 days to encourage callus formation and improve attachment of the graft union while reducing light intensity and transpiration through controlled conditions. Once the callus is fully formed and the wounds have healed, the grafted plants are acclimatized by shifting them to a mist chamber in the greenhouse or placing them under clean plastic to prevent leaf burn and wilting.

Drought stress

- Drought is another serious water stress problem for sustainable vegetable production worldwide, resulting from water deficit under water limiting conditions.
- Water availability is highly affected by climate change which influences crop productivity, specifically that of vegetable crops, and total crop failures are common mean air temperature, could be the reason for the reduced availability of irrigation water.
- An increase in evapotranspiration would also be anticipated under drought conditions, as vegetables contain about 90% water.

Grafting techniques to overcome drought stress

In Europe, eggplant and tomato hybrids, including *Solanum* spp. and interspecific hybrids, are commonly used as rootstocks. Watermelon (*Citrullus lanatus*) is often grafted onto

pumpkin (*Cucurbita moschata*) rootstocks to reduce water stress. Grafting onto drought-tolerant rootstocks has been widely practiced in solanaceous and cucurbitaceous vegetable crops to improve drought tolerance. For example, in tomato, grafting drought-sensitive cultivars with drought-tolerant ones has shown that antioxidant enzyme activity differs between grafted and non-grafted plants under drought stress. In cucumber, grafting has been found to enhance water-use efficiency (WUE) by influencing the ABA biosynthesis pathway, leading to better growth and yield. Similarly, osmotic adjustments corresponding to water stress levels have been observed when sensitive pepper plants are grafted onto relatively tolerant rootstocks. Additionally, grafted tomato plants exhibit improved production of micro and macronutrients, such as vitamins and sugars, which contributes to greater plant vigor and higher economic yield.

Table 2: Rootstock and scion combinations in vegetable crops under induced drought stress

Rootstock	Scion	Key improved Characteristics
PS1313 (*Cucurbita maxima Duchesne* X *Cucurbita moschata Duchesne*)	Watermelon (*Citrullus lanatus* (thumb.) Matsum and Nakal) cv.Ingrid	Enhances water and nutrient uptake and increased CO2 assimilation.
Tomato (*Solanum lycoperiscon*) cv. Beaufort	Tomato (*Solanum lycoperiscon*) cv. M28	Increased total carotenoid and proline content, less reduction in chlorophyll b concentration.

Salinity stress

- Higher concentration of soluble salt in water or soil called as salinity
- Salt affected soil is classified into
- Saline soil
- Alkaline soil (sodic soil)

Table 3: Characteristic Feature of saline and alkaline soil

Feature	Saline soil	Alkaline soil
pH	< 8.2	>8.2
EC	> 4 dS/m	< 4 dS/m
ESP	< 15%	> 15%

Gypsum	Present	Absent
Visible symptom	White layer on top of soil	Dark brown or black or ash color clay crust

Grafting techniques to overcome Salinity stress

- The use of resistant genotypes as the rootstocks was efficient technique for improving crop tolerance to salt stress.
- Interspecific hybrid rootstock has improved the salt tolerance of the grafted tomato plants.
- Muskmelon found that interspecific squash rootstock (*Cucurbita maxima* × *Cucurbita moschata Duch*.) increased salt tolerance, along with plant biomass and leaf area, in the grafted muskmelon compared to non-grafted control plants.
- Eggplant (*Solanum melongena* L.) grafting cultivar "Suqiqie" onto "Torvum Vigor" (*S. Torvum* Swartz) improved the growth performance under saline stress condition
- Grafting watermelon "Fantasy" cultivar onto plants "Strongtosa" rootstock (*Cucurbita maxima* Duch. X *C. moschata* Duch.) reduced the decrease in shoot weight and leaf area caused by the increase in salinity in comparison with ungrafted plants
- Cucumber (*Cucumis sativus*L.), grafting cultivar "Jinchun No. 2" onto bottle gourd rootstock "Chaofeng 8848" (*L. siceraria* Standl.) alleviated the negative effect of salinity on shoot dry weight

Table 4: Rootstock and scion combinations in vegetable crops under induced salinity stress

Rootstock	**Scion**	**Key improved characteristics**	**Reference**
Capsicum chinense Jacq. 'ECU-973' *Capsicum baccatum* L. var. pendulum 'BOL-58'	Pepper (*Capsicum annum*) cv. Adige	Lesser negative impact on the nitrate reductase activity, photosynthetic rate and lipid peroxidation.	Penella*et al.* (2014)
Interspecific squash rootstock (*Cucurbita maxima* Duch. X *Cucurbita moschata* Duch.) 'RS841 improved'	Melon (*Cucumismelo* L.) cv. Brennus and London	Improved plant biomass and leaf area. Better stomatal regulation under salt stress conditions	Orsini*et al.* (2013)

Interspecific tomato hybrid rootstocks (*Solanum lycopersicum* X *S. habrochaites*) 'Maxifort'. 'Arnold' & 'Armstrong'	Tomato (*S. lycopersicum* L.) cv. Cuore di Bue	Higher fruit juice Na+ content	Di Gioia*et al*. (2013)
Cucumber (*Cucumis sativus* L.) cv. Affyne , Cucurbita hybrid rootstock (*Cucurbita maxima* Duch. X *Cucurbita moschata* Duch.) 'P360'	Cucumber (*Cucumis sativus* L.) cv. Ekron	Lesser reduction in chlorophyll content (SPAD index).	Colla*et al*. (2013)

Flooding stress

- Excessive moisture due to unpredictable heavy rainfall adversely affects the production of many vegetable crops due to their high sensitivity to flooding, and some vegetables are in tolerant of flooded soil conditions throughout their growth and development.
- High moisture in the soil causes the reduction of oxygen in the roots of plants by altering photosynthesis and the water potential

Grafting techniques for overcome Flooding stress

- Tomato hybrids (**Arka Rakshak and Arka Samrat**) were grafted onto eggplant rootstocks (IC-354557, IC-111056, IC-374873, and CHBR-2) and exposed to waterlogged conditions.

Table 5: Rootstock and scion combinations in vegetable crops under induced flooding stress

Rootstock	**Scion**	**Key improved characteristics**	**Reference**
Luffa (*Luffa cylindria)* cv. Cylinder	Bitter melon (*Momordia charantia*) cv. New Known	Slight decrease in photosynthetic rate, stomatal conductance, transpiration, and the activity of RuBisCO	Liao & Lin (1996)

Interspecific squash hybrid (*Cucurbita maxima Duchesne X C. Moschata Duchesne*) cv. Shintosa-ichigou	Cucumber (*Cucumis sativus*) cv. Kaga-aonaga fushinari	Triggering ethylene biosynthesis resulting in reduction in chlorophyll degradation	Kato *et al*. (2000)
Lagenaria siceraria (Landrace)	Watermelon (*Citrullus lanatus* (thunb.) Matsum and Nakal) cv. Crimson Tide	Formation of aerenchyma tissue and adventitious roots and the reduction in the chlorophyll loss under flooded conditions	Yetisir *et al*. (2006)
Eggplant (*Solanum melongena*) cv. IC-354557, IC-111056, IC374873, CHBR-2	Tomato (*Solanum lycopersicum*) Hybrid line cv. Arka rakshak, Arka samrat	Less reduction in chlorophyll content .	Bahadur *et al*. (2015)

Thermal stress

- Vegetable crops are highly sensitive to both low and high temperatures

Temperature extremes can result in vegetable production losses:

- Promoting wilt and necrosis, retarding the rate of truss appearance, and impacting the timing of fruit ripening.
- Grafting can be used to protect plants from thermal shock and help plants perform even better in terms of yield due to the associated physiological changes in the grafted plant (Rivero et al. 2003).

Effect of thermal stress

- Tomato, high temperatures cause significant losses in crop productivity due to decreased fruit set, small fruit size, and lower fruit quality.
- Depends on the intensity and length of exposure, low temperature leads to irreversible dysfunction, cell death, and finally plant death.
- Early fruit yield and quality characteristics - influenced by temperature.
- High-temperature conditions ,chilling or low temperature is a serious problem for tomato, squash, cucumber, and watermelon

- Better performance of grafted plants in thermal stress conditions can also be attributed to better RuBisCO activity and higher photosynthetic efficiency (Zhou et al. 2007).
- In Morocco, *C. ficifolia*is also the preferred rootstock for cucumbers and is an excellent rootstock for low soil temperature tolerance - (Besri 2008)

Low temperature stress

- Impact seed germination, Seedling growth , Plant growth is affected , Economic yield loss

Table 6: Rootstock and scion combinations in vegetable crops under induced thermal stress

Rootstock	**Scion**	**Key improved characteristics**	**Reference**
Tomato (*Solanum lycopersicum*) cv. RX-335	Tomato (*Solanum lycopersicum*) cv. Tmknvf2	✓ Increased PAL activity ✓ Decreased PPO and GPX activity ✓ Decrease in dry weight ✓ Increase in total phenols	Rivero *et al.* (2003)
Tomato (*Solanum lycopersicum*) cv. LA1778	Tomato (*Solanum lycopersicum*) cv. T5	Root hydraulic conductance and stomatal conductance were maintained in grafted plants	Bloom *et al.* (2004)
Tomato (*Solanum habrochaites*) breeding line LA1777	Tomato (*Solanum lycopersicum*) cv. Money maker	✓ Higher root mass ratio. ✓ High total leaf carbon concentration	Venema *et al.* (2008)
Tomato (*Solanum lycopersicum*) cv. Summerset and Eggplant (*Solanum melongena*) cv. Black Beauty	Tomato (*Solanum lycopersicum*) cv. UC 82-B	✓ Larger leaf area, more leaf fresh and dry weight. ✓ Higher chlorophyll fluorescence. ✓ More pollen grains/flower	Abdelmageed &Gruda(2009)

Table 7: Characteristics of root stock species with desirable trait for different crop

CROP	ROOTSTOCK SPECIES	DESIRABLE TRAITS
Tomato	Lycopersicon pimipinellifolium	Nematode resistance
	Lycopersicon hirsutum	Nematode resistance
	Solanum integrifolium	Tomato sugar content
	Solanum sisymbrifolium	Disease resistance
	Solanum torvum	Nematode tolerance
	Solanum nigrum	Fruit size and quality
Brinjal	Solanum torvum	Disease resistance, nematode tolerance
	Solanum integrifolium	Low temperature tolerance
Water melon	Lagenaria siceraria	Vigorous root system, fusarium tolerance, low temperature tolerance
	Cucurbita moschata	Vigorous root system, fusarium tolerance, low temperature tolerance
	Benincasa hispida	Good disease resistance
	Cucurbita pepo	Vigorous root system, fusarium tolerance, low temperature tolerance
	Cucumis metuliferus	Fusarium tolerance, nematode resistance
Cucumber	Cucurbita ficifolia	Low temperature tolerance, good disease resistance
	Cucurbita maxima X Cucurbita moschata	Low temperature tolerance and fusarium resistance
	Cucumis metuliferus	Fusarium tolerance, nematode resistance

Table 8: Different rootstocks suitable for grafting

Scion	Root stocks
Cucumber	Cucurbita moschata, Cucurbita ficifolia ,Cucurbita maxima
Melons	Cucurbita Sp, Cucumis melo, Benincasa hispida
Water melon	Citrullus lanatus ,Cucurbita moschata, Cucurbita maxima, Cucurbita moschata X Cucurbita maxima, Lagenaria siceraria

Bitter gourd	Luffa sp, Lagenaria siceraria, Cucurbita moschata
Tomato	Lycopersicon pimpinellifolium , L. esculentum, Solanum nigrum
Egg plant	Solanum nigrum ,S. torvum, S.integrifolium, S.melongena

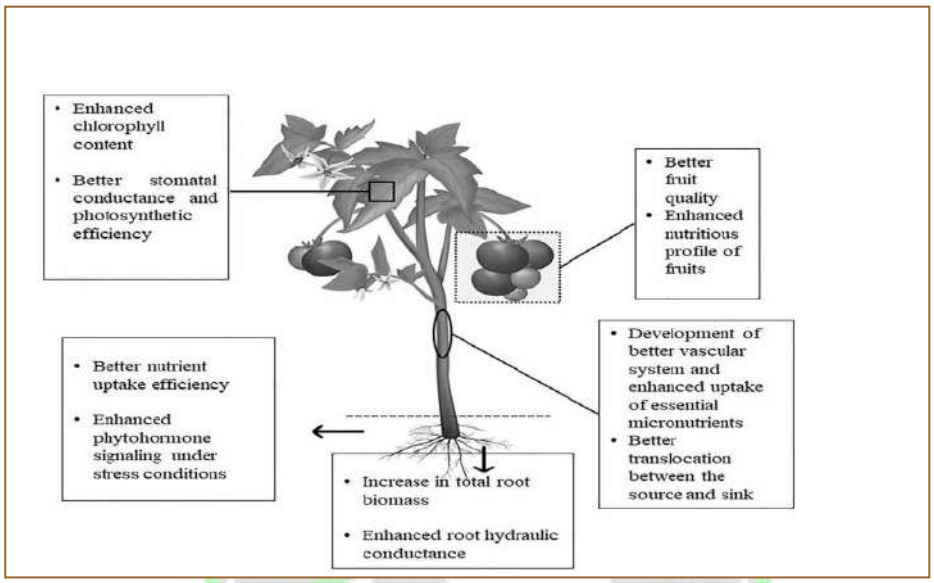

Fig 1: Illustration of the physiological and morphological benefits of grafted vegetable crops that enable abiotic stress tolerance.

Occurrences of problems during grafting of vegetable; various problems related to the production and management of grafted transplants is following:

- This technique requires large amount of intensive labour and specialized trained workers.
- It required time management for rootstock and scion seeds sowing.
- It required a controlled environment for graft healing.
- During the initial stages or after transplantation under field conditions, Rootstock-scion incompatibility is observed.

Conclusion

Grafting serves as a sustainable strategy to enhance abiotic stress tolerance in vegetable crops, ensuring improved productivity and resilience. Its wider adoption can reduce crop losses and promote sustainable farming under changing climatic conditions.

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GREENGRAM - YELLOW MOSAIC VIRUS

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Abstract

Green gram yellow mosaic virus (GMYMV) is a serious disease causing severe yield losses in green gram. It is caused by *Mungbean yellow mosaic India virus* (MYMIV) or *Mungbean yellow mosaic virus* (MYMV) of the family *Geminiviridae*. The virus is transmitted mainly by the whitefly (*Bemisia tabaci*) and to a lesser extent through seeds. Symptoms include bright yellow mosaic patterns, stunted growth, poor flowering and reduced pod formation.Favourable conditions include temperatures of 21–26°C, high humidity and presence of weed hosts. Weeds such as *Croton sparsiflorus* and *Acalypha indica* serve as reservoirs for the virus. Management is difficult due to the persistent nature of the virus and its vector. Integrated Disease Management is the most effective approach. This includes cultural, chemical, mechanical, biological and botanical control methods. Adopting IDM practices is essential to minimize losses and sustain green gram production in endemic regions.

Introduction

Green gram also known as mung bean**,** is a versatile and nutritious pulse crop, widely cultivated in India and other parts of Asia. It is a short-duration crop, rich in protein and can be consumed in various forms including whole grains, split pulse (dal) or sprouted. Green gram is also valuable for its use as green manure and fodder. Green gram is an important pulse crop for Indian agriculture, contributing to food security and soil health. It is also used as a green manure and fodder crop, improving soil fertility and providing feed for livestock. Green gram

can be cultivated in different seasons, including kharif, rabi, and summer. In India, it is often grown as a summer crop after the harvest of other crops like peas, gram, or potatoes.

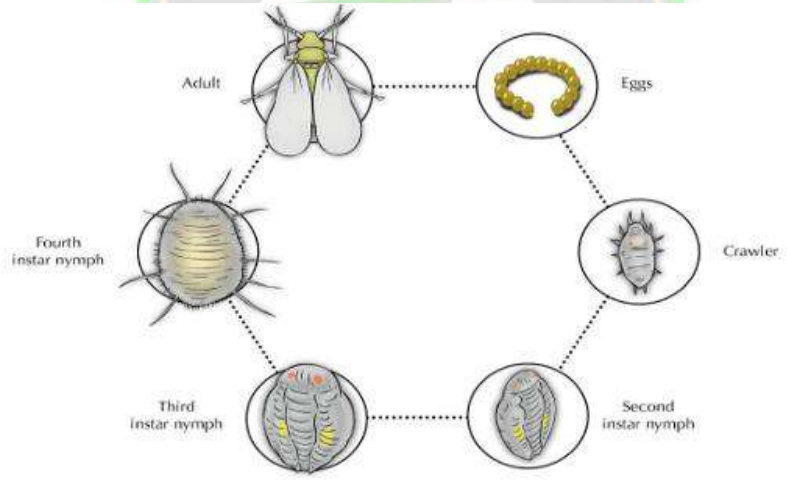
Pathogen

It is caused by *Mungbean yellow mosaic India virus* (MYMIV) in Northern and Central region and *Mungbean yellow mosaic virus* (MYMV) in western and southern regions. It is a Begomovirus belonging to the family geminiviridae. The virus particles are ssDNA, bipartite genome with two gemonic components DNA-A and DNA-B.

MODES OF TRANSMISSION AND VECTORS:

Insect Vectors:

The primary mode of YMV transmission is through insect vectors, mainly whiteflies (*Bemisia tabaci*) and occasionally aphids (Aphis craccivora). These vectors acquire the virus by feeding on infected plants and then transmit it to healthy plants during subsequent feeding. Whiteflies are considered the most efficient vectors for YMV transmission .



Seed Transmission:

YMV can also be transmitted through infected seeds. Infected seeds act as a source of primary infection in a new crop season. However, the contribution of seed transmission to overall YMV spread is relatively low compared to insect-mediated transmission.

Symptoms

- Initially small yellow patches or spots appear on green lamina of young leaves. Soon it develops into a characteristics bright yellow mosaic or golden yellow mosaic symptom.

- ❖ Yellow discoloration slowly increases and leaves turn completely yellow.
- ❖ Infected plants mature later and bear few flowers and pods.
- ❖ The pods are small and distorted.
- ❖ Early infection causes death of the plant before seed set.

Favourable Conditions:

Temperature: A temperature range of 21-26°C is ideal for the virus to flourish.

Humidity: High humidity, including heavy dews at night, creates a favorable environment for the virus to spread

Weather patterns: Cloudy, humid weather, and prolonged dry spells followed by irrigation also favour the virus.

Secondary spread: The virus is spread by air-borne conidia (spores) produced during the growing season.

Vector presence: Whiteflies – *Bemisia tabaci* is the primary vector for transmitting the *Mung Bean Yellow Mosaic Virus*

Weeds: Weed hosts like *Croton sparsiflorus, Acalypha indica, Eclipta alba and Cosmos pinnatus* and legume hosts. It. can also act as reservoirs for the virus, especially during the off-season, and can be a source of infection for green gram.

INTEGRATED DISEASE MANAGEMENT:

1.CULTURAL METHODS:

- ✓ Rogue out virus infected plants upto 25 DAS

- ✓ Remove the weed hosts periodicallyIncrease the seed rate (25 kg/ha).Cultivate the crop during rabi season.
- ✓ Follow mixed cropping by growing two rows of maize (60 x 30 cm) or sorghum (45 x 15 cm) or cumbu (45 x 15 cm) for every 15 rows of black gram or green gram.

2.CHEMICAL METHOD:

- ✓ Treat the seeds with Thiomethoxam-70WS or Imidacloprid-70WS @4g/kg
- ✓ Seed treatment with Dimethoate (or) Imidacloprid @ 5 ml /kg.
- ✓ spray with triazophos 40 EC @ 2.0 ml/l or malathion 50 EC @ 2.0 ml/l or oxydemeton methyl 25 EC @ 2.0 ml/l at 10-15 days
- ✓ Spray methyl demeton 25 EC 500 ml/ha or dimethoate 30 EC 500 ml/ha or thiamethoxam 75 WS 1g /3 lit for control of white flies and repeat after 15 days, if necessary.
- ✓ Spray Thiamethoxam-25WG @ 100g or Imidacloprid 17.8% SL @ 100 ml in 500 lit of water.

3.MECHANICAL METHOD:

- ✓ Installing yellow sticky traps @ 5 Nos. / acre

4.BIOLOGICAL METHOD:

- ✓ Grow resistant green gram variety like Pant Moong-3, Pusa Vishal, Basanti, ML-5, ML-337, PDM-54 and Samrat.
- ✓ Growing resistant varieties such as VBN 4, VBN 6 and VBN 7.

5.USE OF BOTANICALS :

- ✓ Foliar spray of nochi leaf extract 10% at 30 DAS.

Conclusion

Green gram yellow mosaic virus is one of the most destructive viral diseases affecting green gram, causing severe yield losses through stunted growth, chlorotic mosaic symptoms, and reduced pod formation. Its transmission primarily through the whitefly (*Bemisia tabaci*) makes management challenging, especially under favorable vector conditions. Effective control relies on an integrated approach involving the use of resistant varieties, timely sowing, vector control, and cultural practices that reduce disease spread. Sustainable management is essential to safeguard productivity, minimize economic losses, and ensure the stability of green gram cultivation in endemic areas.

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IMPACT OF DEMONETIZATION IN INDIA IN AGRICULTURE SECTOR

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Abstract

The agricultural sector in India was seriously impacted by demonetization, which refers to the process of eliminating a currency unit's legal tender status. In order to eradicate black money, counterfeit currency, terror financing and corruption, as well as to encourage digitization the Rs.500 and Rs.1000 notes, which made up 86.8% of the currency in circulation, were demonetized in 2016. Because the majority of agricultural transactions are made in cash, this resulting liquidity constraint had a negative influence on the buying of seeds and fertilizer, which in turn hindered sowing and production. Small and marginal farmers were disproportionately impacted by decreased sales, increased waste and decreased price realization. Both Kharif and Rabi cultivations were reduced accounts of decreased demand, lower prices, and postponed sowing were reported.

Introduction

The process of transforming something into legal money is known as monetization. It relates to the process by which central banks generate cash or print banknotes. Removing a currency unit's legal tender status is known as demonetization. Demonetization 2016 was a far-reaching decision made with the goal of cleaning up the Indian economy and nudging it toward greater formalization and digitization. It was the third decision, the prior two being made on January 12, 1946, and January 16, 1978, with partial success. The Prime Minister himself announced the decision to demonetize the high value currency notes of denomination Rs. 1000 and Rs. 500 valued at Rs. 15.44 trillion, which constituted 86.9 percent of the total currency

under circulation. The importance of the matter, this was evidently guided by the aim of reaping the immense potential medium-term benefits in the form of minimized corruption, greater digitization of the economy and a rise of financial savings.

History for Demonetization in India

First Currency Ban: The 1000 and 10,000 rupee notes were taken out of circulation in 1946. Because the general public could not afford such larger denomination cash, the impact was smaller. 1954 saw the revival of the notes along with the introduction of Rs 5000 in new currency.

Second Currency Ban: The Prime minister of India, Morarji Desai declared in 1978 that Rs. 1000, Rs. 5000, and Rs. 10,000 would no longer be in circulation. The ban's only goal was to curb the nation's production of black money.

Third Currency Ban: The Indian government made the decision to demonetize the 500 and 1000 rupee notes on November 8, 2016. These notes accounted for 86 % of the country's circulating cash.

Reason for Demonetization

- Black money can have many forms, including cash, real estate investments, luxury items like jewelry, and transactions with private financiers and foreign currency traders. The goal was to get black cash out so that it could lose its anonymity and become ubiquitous.
- **Counterfeit Currency:** Foreign adversaries were promoting counterfeit currency to undermine India's economy. Once the old currency has been withdrawn, the counterfeit becomes useless. It cannot be deposited in a bank either.
- **Terror Financing:** Cash was mostly used for terror financing in J&K, as well as maoist and naxalite activities in the central region. Once the currency was demonetized, the money held by such groups became ineffective and could not be used for such purposes.
- **Corruption:** Corruption in public life, which involves unlawful gratification for assisting others, is often facilitated through cash transactions.
- **Digitization and Formalization of the Economy:** A significant portion of the Indian economy was still operated using the cash system, which the tax department was unable to track because it left no trace. As a result, the government considered encouraging the formalization and digitization of the economy through e-wallets, online transactions and an array of payment methods such as Paytm, Rupay cards and the BHIM app.

Impact of Demonetization in Agriculture

Agriculture is the largest sector of the economy in terms of employment and demonetization has had a negative impact on it. The majority of transactions in this sector take place in cash, and the liquidity crisis hampered the purchase of seeds and fertilizer, resulting in reduced sowing and agricultural productivity leads to price fall. Retail vegetable dealers had another challenge: a lack of demand for their perishable commodities, resulting in a lot of produce being wasted. Because there was a severe shortage of Rs.500 denomination notes and change for the high denomination Rs.2000 notes was not readily accessible with the vegetable and fruit dealers, their sales suffered. This also shifted shoppers away from local vendors and toward large retail markets, affecting the livelihood of the unorganized sector.

Agriculture is primarily financed by cooperative banks, which were prevented from exchanging and depositing demonetized currency, harming to the farmers. Agricultural output is sold, marketed and distributed through mandis are primarily cash-based and supply chain disruptions occurred during demonetization. Farmers who did not have PAN cards, which are required for bank transactions over Rs.50,000 were also unable to purchase farm machinery. The absence of banking services and ATMs in rural areas impacted cash availability, with farmers, illegal moneylenders, black marketers, and intermediaries taking advantage of the situation.

Impact on Kharif Cultivation

At the time of demonetization, farmers had harvested kharif crops to sell in the markets. However, the decrease in consumer demand caused by the cash shortage resulted in farmers receiving lower prices for their produce.

According to Sumathy and Savitha (2017), farmers suffered a setback as demand for vegetable farmers fell in wholesale markets. After demonetization, market arrivals and perishable prices declined. Perishable arrivals and prices in the majority of markets fell by 4 to 5 percent (Shahare, 2017). Wholesalers were more affected with 6.6 % than retailers (Bisen et al 2017). Small and marginal farmers were disproportionately affected compared to large farmers.

Impact on Rabi Cultivation

Sowing activities for Rabi crops were hampered since farmers were unable to purchase seeds or pay laborers to start sowing. So, farmers reused old seeds from the previous year's harvest for sowing due to a lack of funds to purchase certified HYV seeds from the market, which may have an impact on crop yields despite this year's good monsoon (Sumathy and

Savitha, 2017). According to Bisenet et al. (2017), 65 per cent of farmers reported a delay in sowing due to demonetization, with small farmers accounting for 54 per cent of the total.

The area under wheat and pulses expanded, whereas rice and coarse cereals dropped (Chand, 2017). The overall rise in Rabi crop acreage this year, despite demonetization, may be assigned to the government's decision of boosting minimum support prices for Rabi crops. Another significant cause for the delay in sowing was a lack of credit. Farmers' access to credit was constrained by the ban on main agricultural cooperative credit societies accepting old notes from farmers, as more than 60% of the rural population transacted through the cooperative sector (The Hindu, 14 December 2016).

Farmers were either unable to deposit the cash received from the sale of kharif crops or repay crop debts. As PACBs struggled with debt recovery and could only withdraw a maximum of Rs. 20000 per week, they were unable to grant more crop loans to farmers. Farmers without a KCC account were the most affected, as they were unable to withdraw Rs. 25000 per week from their crop loans. Farmers were compelled to rely on non-institutional loan sources for financing. As a result, the imposition of cash withdrawal limits and a lack of access to agricultural loans hampered the timely operation of cultivation activities since farmers lacked the funds to pay laborers, purchase fertilizers, and so on.

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MULTI PARENT ADVANCED GENERATION INTER-CROSS (MAGIC) AND ITS PROSPECTS IN CROP IMPROVEMENT

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Introduction

Innovative Breeding approaches are evolving day by day to tap the genetic diversity available in a population. Multiparent advanced generation inter-cross (MAGIC) admixture populations have gained popularity as a genetic resource recently for mapping and creating breeding lines with a variety of desirable features. Multi-parent advanced generation inter-cross (MAGIC) populations are large sets of recombinant inbred lines (RILs) that are a genetic mosaic of multiple founder parents. MAGIC involves repeatedly mating of several inbred ancestors, fusing the genetic makeup of all the ancestors into a single line. Four separate single crosses are created by crossing eight parental lines in pairs. Parent line can be an inbred line, a clone, or an individual selected for origin or use. To create two double crosses, these single crosses are crossed in pairs. To develop a broad genetic foundation, eight parents are typically intercrossed. Next, the inbred founders are paired off and intermated in a specific order for each line, a process called a funnel. The mixing stage will take "n" generations if each recombinant inbred line (RIL) is the consequence of a 2 "n"-way cross. Eight paternal complicated crossings are created once two double crosses are finally mated. The multi-parent advanced generation inter-cross (MAGIC), was firstly proposed by Mackay and Powell (2007). By mixing and recombining the genomes of multiple founders, multi-parent populations combine many commonly sought beneficial properties of genetic mapping populations. Many multi-parent populations have been constructed in crop species, and their inbred germplasm and associated phenotypic and genotypic

data serve as enduring resources. Their utility has grown from being a tool for mapping quantitative trait loci to a means of providing germplasm for breeding programmes.

Multi parent population

Bi-parental populations, derived from crosses between two inbred lines, have been the standard design for genetic mapping in crops. In contrast, the MAGIC design is more complex. MAGIC is an extension of AIC in some respects, except several founders are inter-crossed over multiple generations before selfing to generate inbred lines. MAGIC populations typically descend from 4, 8 or 16 parents, consistent with a simple funnel breeding design (Fig. 1; Huang et al. 2015). This is however not completely strict in nature, and for instance, the first MAGIC population in *A. thaliana* used 19 parents (Kover et al. 2009). Each MAGIC line usually inherits alleles from all parents, and MAGIC chromosomes are random mosaics of the founder haplotypes. By capturing increased genetic recombination and genetic variation, MAGIC populations are designed to address both of the principal limitations of bi-parental populations for QTL mapping. Founder selection is a key issue in MPP design because it determines the pool of genetic variation that segregates in the population.

Steps involved in generation of MAGIC population (Shinde et al. 2022)

There are four steps involved in generation of MAGIC population

1. Founder selection
2. Mixing of parents
3. Advanced intercrossing
4. Inbreeding

1. Founder selection

Founder lines must be chosen before initiating a population development. Choosing the founders will be one of the most crucial factors and largely depend on the objective of synthesizing the population. This could be based on genetic or phenotypic diversity, either in a restricted collection of material (such as elite cultivars or geographical adaptation) or material with a wider range of ancestries (worldwide germplasm collections, distant relatives). Founders selected solely on relevance to a breeding programme for specific traits may result in a MAGIC population that more quickly translates into superior breeding lines. More diversified founder sets may provide biological knowledge into a wide variety of attributes. In some species, genetic incompatibility can significantly reduce the number of offspring that may result from particular

crosses. However, limited genetic variabiity might make it difficult to calculate founder probabilities and restrict researchers from making the most out of their populations. To create a resource that is also useful, the phenotypic variability must be carefully maintained in addition to the genetic diversity. This will not only help with phenotypic evaluation in the future but will also make cross-breeding easier.

2. Mixing of parents

Multiple parents are crossed among each other during the earlier phase of population development to create a large genetic base. During this stage, the inbred founders are paired off and interbred in a specific order for each line calling it a funnel. The mixing stage will take 'n' generations if each recombinant inbred line (RIL) is a result of a '2n'-way cross. A group of lines with genomes made up of contributions from each of the founders are the end product of this stage.

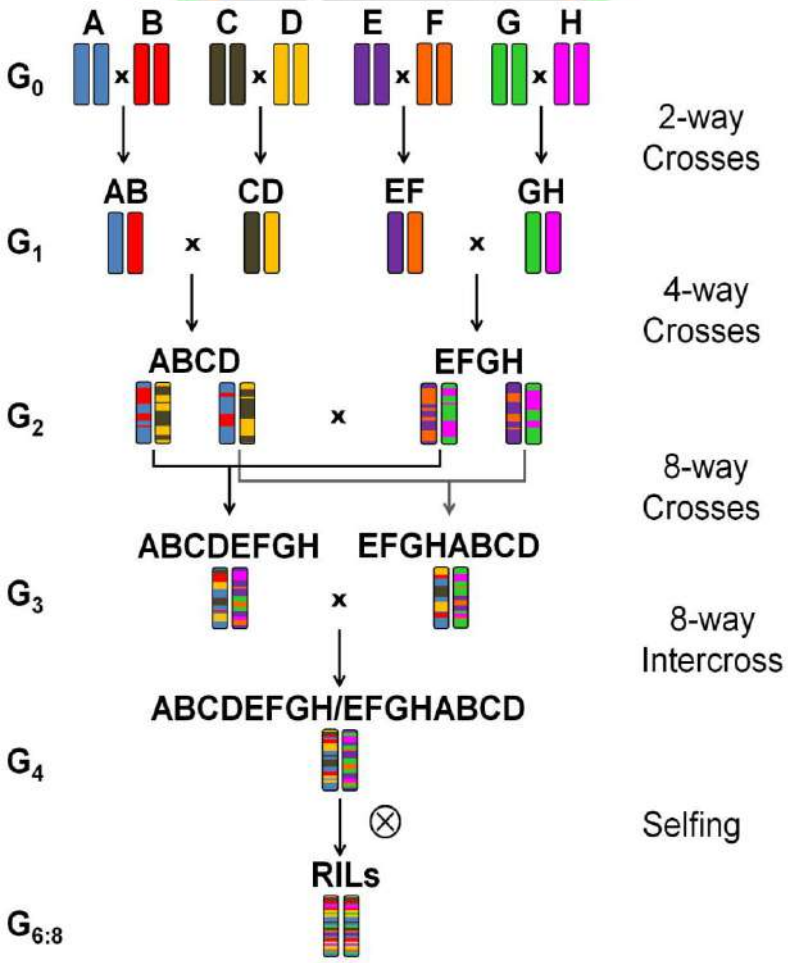

Fig 1. Multi Parent Population Design (Funnel)

The design and choice of the funnels involved in the cross will have an effect on the final genetic make-up of the population. Although it would demand more investment in terms of money and time, more variation in the funnel types developed will assure more robustness in accounting for issues like maternal effects, population structure and segregation distortion. The degree of relatedness resulting from common recombination events is a further issue when producing a small number of funnels. Genetic diversity will be decreased if there are fewer individuals in any generation since those who are derived from them will be associated to each other as well. If properly taken into account, this relatedness can also lead to population structure, which will bias assessments like linkage map building and QTL mapping.

3. Advanced intercrossing

As in the advanced intercross (AIC), the mixed lines from several funnels are progressively and randomly intercrossed in the second stage. The primary aim of the intercrossing is to enhance the population's recombination rate (Darvasi and Soller, 1995). Significant increases in QTL mapping power required at least six cycles of intercrossing as reported by Yamamoto et al., 2014.

4. Inbreeding

The final step involves progressing the individuals from the advanced intercrossing stage to produce homozygous individuals. In plants, single seed descent (Gaulden, 1939) or doubled haploid production can result in RILs (Blackslee et al., 1922). In practice, except for double haploid lines, the population's offspring won't be entirely inbred. This remaining heterozygosity has both potential benefits and drawbacks. Due to the inability to differentiate heterozygotes for some markers in genotyping, particularly for polyploids and genotyping by sequencing (GBS) methods, there may be problems (Elshire et al.2011) which estimates genotype probabilities for people in intermediate generations with high heterozygosity, as it may present problems in data analysis by violating the simple condition of full inbreeding (Broman, 2005). Therefore, the expected amount of genome heterozygosity is less than 3%. In general, it takes at least 8 crop seasons to mature MAGIC populations to the S5 generation.

Applications of MPPs

There are several examples where MAGIC germplasm has been used for pre-breeding or released in their own right as a variety. MAGIC and MAGIC-like populations have now been developed across a range of plant and crop species, including model organisms like Arabidopsis

as well as major crops like wheat, rice, and maize. The pioneering mouse collaborative cross was the first MAGIC population developed, paving the way for the application of this powerful quantitative genetics approach to mapping complex traits in crops.

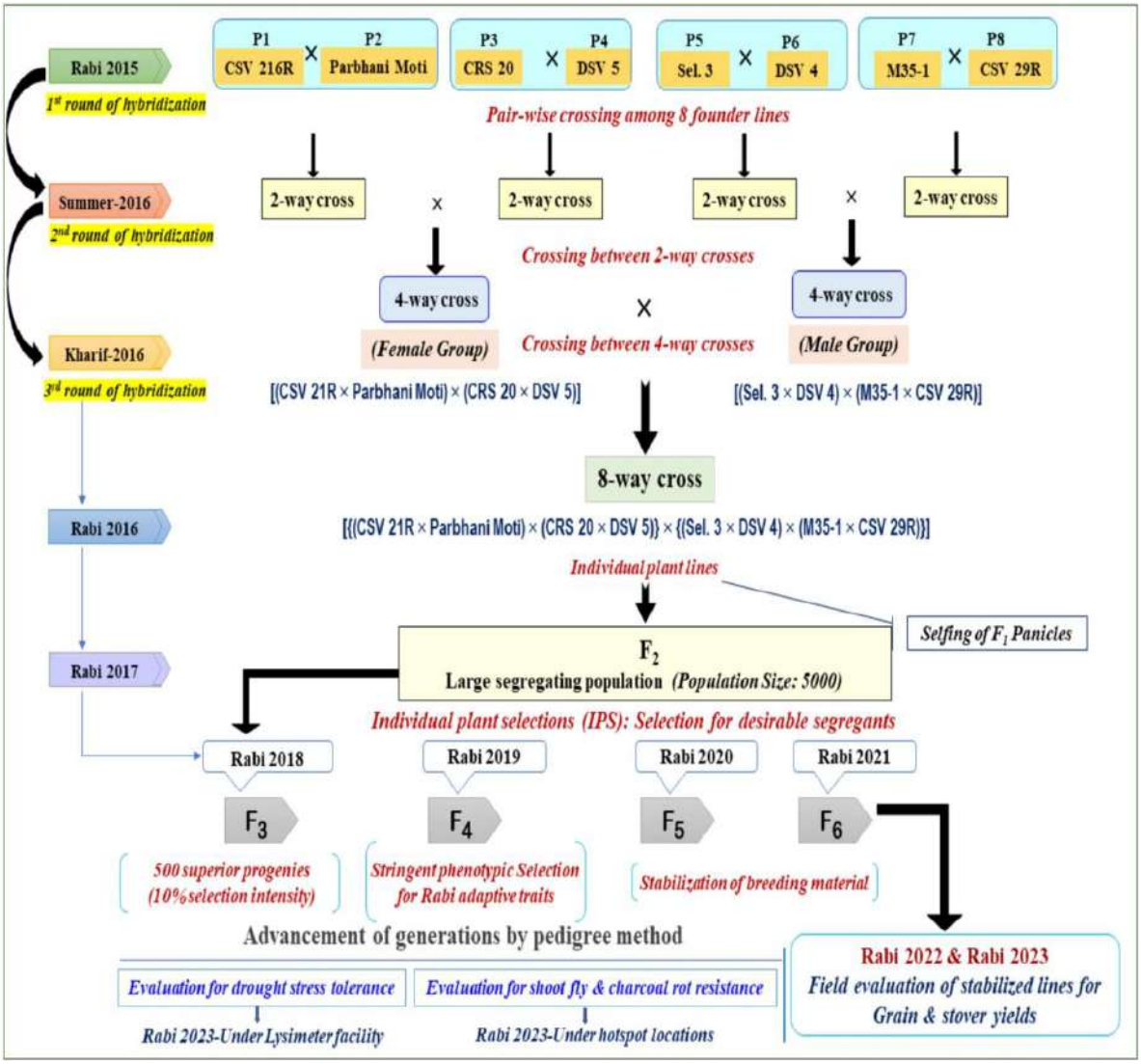

Fig 2. Schematic representation of high yielding stress resilient post- rainy season sorghum cultivars using multi parent crossing approach

Since then, several MAGIC populations have been developed and used for quantitative trait locus discoveries in other major field crops including wheat, rice, tomato, faba bean, maize, barley, soybean and sorghum Li et al. (2014) reported that a RIL from a rice MAGIC population was released as a new variety in China. Separate rice MAGIC populations developed at the International Rice Research Institute (IRRI) have also been used; the MAGIC RIL, IR 95099:7-B-2-10-10-2, is in the pipeline of varietal release in southern Vietnam on the basis of its

maturation date, yield and grain quality, which were assessed in trials at the Cuu Long Delta Rice Research Institute, Can Tho, Vietnam. In chickpea, RILs from MAGIC populations developed at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) have been directly released as new varieties, as well as used as donors in commercial breeding programmes. Post-rainy season sorghum genotypes were developed with enhanced yield potential and improved tolerance to drought, shoot fly, and charcoal rot of a multi-parent crossing approach using 17 founder lines by IIMR, Solapur, Maharashtra (Fig 2.and Patroti et. al. 2025). From a 16- founder wheat MAGIC population developed at NIAB, 24 MAGIC RILs have been selected for inclusion in commercial breeding programmes on the basis of their yield, ear weight and protein content. Thus, the collection of phenotypic data across several agronomically important traits in MPPs facilitates the identification of promising lines.

Utility of MAGIC population in Crop Improvement

1. MAGIC populations can be used to create varieties with more number of agronomically useful characters.
2. MAGIC can help enhance the genetic diversity so that the population/ variety can be adapted to a wide range of locations and of different climatic circumstances.
3. MAGIC can offer solutions for a variety of production-related problems viz., biotic and abiotic stresses.
4. MAGIC population may serve as a Pre-breeding material for direct extraction and creation of breeding lines and varieties.
5. MAGIC will have a significant impact on agricultural output and have the potential to alter how scientists find the genes that affect quality and disease resistance.

However there exist some limitations in development and utility of MAGIC population

1. It needs skilled labour for crossing and needs more input and time.
2. For the recovery of recombinants with all the desired features, a large population size is necessary which may be difficult to handle.
3. For a certain attribute, large-scale phenotyping is necessary.
4. A significant decrease in the number of offspring might result from parental incompatibility.
5. Better marker system is necessary to detect QTL.
6. If less diverse parents are selected then it‟s difficult to get desirable recombination for the focused study.

Conclusion

Despite the complexity and the resources required in their development, due to their potential and interest for breeding, the number of MAGIC populations available and under development is continuously growing, with 45 MAGIC populations in different crops being reported so far. As the number of MAGIC populations is continuously growing, new tools for an efficient analysis of MAGIC populations have recently been developed.

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CRACKING THE CODE: GENE KNOCKOUT AND SILENCING TECHNIOUES SHAPING OUR FUTURE

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Abstract

In genetic research, gene knockout and silencing technologies are revolutionary tools that allow for precise control over gene expression to improve biotechnology, medicine, and agriculture. By permanently deactivating or deleting target genes, gene knockout enables scientists to examine how genes function by observing phenotypic changes. By destroying mRNA without changing the DNA sequence, gene silencing techniques such as RNA interference (RNAi), virus-induced gene silencing (VIGS), and hairpin RNA (shRNA) temporarily suppress gene expression. Both silencing and knockout are essential for genetic research and the development of new treatments because they offer reversible and tissue-specific regulation and permanent modifications, respectively. Together, these technologies open up new avenues for disease prevention, gene function research, and agricultural sustainability, paving the way for a time when precise genetic control will be used to address global health and food security issues.

Key words: Gene knock out, gene silencing, PTGS, VIGS, shRNA

Introduction: The Power of Turning Genes Off

Imagine if we could hit the "mute" button on a gene causing a deadly disease or delay a tomato from going soft just days after buying it. Thanks to gene silencing and knockout

technologies, scientists are doing exactly that. From fighting cancer to boosting crop yields, gene knockout approaches are revolutionizing medicine, agriculture, and biotechnology. By blocking harmful genes or temporarily shutting down their activity, researchers are finding new ways to cure diseases, extend the shelf life of food, and improve crop resistance.

What Is Gene Knockout?

Gene knockout is a technique that involves selective inactivation of a target gene either permanently disabling or deleting a specific gene, within an organism's genome using artificial means. This helps scientists to study the function of that gene by observing what changes occur when it's no longer active. There are two main types of knockouts:

- **Complete knockout**: The gene is permanently inactivated.
- **Conditional knockout**: The gene can be selectively turned off at specific times or in specific tissues.

Gene knockout is a powerful tool in genetic research, helping identify genes involved in diseases, development, or specific plant and animal traits.

Gene Silencing: A Softer Approach

While knockout involves cutting out or disabling a gene, gene silencing is a more subtle strategy. It is the suppression of gene expression without altering the DNA sequence that is deactivating a gene by disrupting its mRNA (Malakondaiah et al., 2024). In gene silencing instead of changing the DNA, it blocks the gene's messenger RNA (mRNA), the molecule that carries genetic instructions for protein production. Silencing prevents the mRNA from being translated into protein, effectively deactivating its activity without altering the DNA code.

Types of Gene Silencing

Post-Transcriptional Gene Silencing (PTGS)

One of the simplest ways to silence a gene is to use antisense RNA—a synthetic strand that is complementary to the gene's mRNA. When the antisense RNA binds to the mRNA, it blocks ribosomes from translating the message into protein. In some cases, the mRNA is also degraded by enzymes such as RNase H. Antisense technology has been used in both research and medicine, including the development of FDA-approved therapies like *Spinraza* for spinal muscular atrophy.

RNA interference is a natural gene regulation process involving small interfering RNAs (siRNAs) and microRNAs (miRNAs). These molecules bind to mRNA and guide it to a protein

complex called RISC (RNA-Induced Silencing Complex), which cuts up the message and prevents protein production (Trasser et al., 2024). This method is highly specific and has opened new doors in genetic therapy and crop improvement.

Virus-Induced Gene Silencing (VIGS)

Virus-Induced Gene Silencing (VIGS) is a plant-specific gene silencing tool that uses the plant's own immune response to silence target genes. It is especially useful in agricultural research for studying gene function and improving crop traits (Shi et al., 2021). In VIGS, a harmless virus is engineered to carry a small fragment of the target gene. When the plant is "infected," it recognizes the viral RNA as foreign and activates an RNA-based defense mechanism. This response includes the formation of double-stranded RNA (dsRNA), which is then processed into siRNAs by an enzyme called Dicer. These siRNAs guide the RISC complex to degrade the plant's own mRNA that matches the viral sequence—effectively silencing the gene.

VIGS is widely used because it is fast, does not involve permanent DNA changes, and can be applied to many plant species. However, it is temporary, often lasting only a few weeks, and not all genes can be completely silenced.

Hairpin RNA (shRNA) Mediated Gene Silencing

Another powerful RNAi-based tool is hairpin RNA (shRNA) silencing. In this method, a synthetic gene construct is designed to contain an inverted repeat of the target gene sequence. When expressed in the plant, it folds into a stem-loop structure (a hairpin), forming double-stranded RNA. This hairpin RNA is processed by Dicer into siRNAs, which then guide the RISC complex to degrade the target mRNA, stopping gene expression (Asadi, Mohammadi, Rezanejad, & Millar, 2024). This method is often used to create stable, long-term gene knockdowns in plants and animals.

Applications of Gene Silencing

Gene silencing plays a crucial role in treating genetic disorders by targeting disease-causing genes, such as the mutant *huntingtin* gene in Huntington's disease. In cancer therapy, it effectively silences oncogenes like the *BCR-ABL* fusion gene in chronic myelogenous leukemia (CML). It also combats viral infections, including HPV and West Nile virus, by disrupting viral gene expression. Additionally, researchers utilize gene silencing to investigate genes associated

with neurological and respiratory diseases. Beyond disease research, it supports drug discovery by helping identify and validate potential drug targets through gene knockdown studies.

In agriculture, gene silencing techniques like RNA interference (RNAi) enhance crop resistance against pests and diseases. They also modify plant metabolism to introduce beneficial traits, such as the non-browning feature in Arctic Apples. Importantly, this approach offers a non-GMO alternative for crop improvement, bypassing the regulatory challenges associated with genetically modified organisms (Koeppe, Kawchuk, & Kalischuk, 2023).

Scientists rely on gene silencing to study gene function by selectively deactivating genes and analyzing the resulting phenotypic changes. In biotechnology, industries apply these methods to optimize the production of biofuels, recombinant proteins, and other bioproducts. Furthermore, gene silencing complements gene editing by enabling precise gene knockouts or fine-tuning gene expression levels (Koch & Wassenegger, 2021).

Commercially, RNAi-based solutions are widely adopted to control viral diseases in plants. The food industry has also embraced gene silencing, using it to develop enhanced products such as non-browning apples (Malakondaiah et al., 2024). These applications highlight the versatility of gene silencing in driving innovation across multiple sectors.

Conclusion

Gene knockout and gene silencing technologies have given scientists powerful tools to explore and reshape biology. From treating genetic disorders to growing better fruits and vegetables, these methods offer a future where we don't just treat symptoms, we silence the cause. Whether using viruses to activate plant defences, folding RNA into tiny hairpins, or delivering antisense strands to block disease genes, the ability to "turn off" specific genes is transforming how we understand and manipulate life. In the ever-evolving story of genetics, sometimes the most powerful move is knowing when to stay silent.

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APPLICATION OF QR CODES IN PLANT IDENTIFICATION: A CASE STUDY ON *MITRAGYNA PARVIFOLIA*

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Abstract

Mitragyna parvifolia (Roxb.) Korth., a deciduous tree belonging to the Rubiaceae family, holds significant ecological, medicinal, and economic value. This study explores an innovative approach to disseminating information about *M. parvifolia* using QR (Quick Response) codes in botanical gardens, national parks, and nature reserves. Field surveys, primary and secondary data collection, and digital tools were employed to create an interactive educational platform. The generated QR codes link to a blog containing detailed information about the species, including its botanical characteristics, distribution, medicinal uses, and conservation status. This method enhances visitor engagement, promotes ecological education, and supports sustainable park management.

Keywords: QR code, botanical education, conservation, digital dissemination

Introduction

Globally, education systems are adopting digital technologies to enhance knowledge and skills in plant specimen studies. Mobile devices such as smartphones and tablets are now widely used for educational purposes due to their portability, affordability, and internet connectivity. This has led to the rise of mobile learning (m-learning), offering flexible, interactive education beyond the classroom.

QR codes, invented in 1994 by Denso-Wave, are two-dimensional barcodes capable of storing various data types like text and URLs. In education, QR codes are increasingly used for

seminar registration, attendance tracking, digital library access, and sharing information. Their advantages include high data capacity, resistance to damage, ease of scanning from any direction, and size scalability (Querini et al., 2018; Muhammad Fabio et al., 2021; Zen Munamwar, 2019). Studies have also explored their use in plant identification and botanical education (Barbosa, 2016; Mukmin et al., 2018; Muh et al., 2022; Naveenkumar, 2022).

This study highlights *Mitragyna parvifolia* (**Kadam/Kaim/Kalamb**), a deciduous tree from the Rubiaceae family, native to South Asia. Found in dry forests and hills, it is valued for its fast growth, drought tolerance, and ecological benefits like soil stabilization and biodiversity support. It reaches 15–20 meters in height, identified by its grey bark, ovate leaves, globose flower heads, and winged seeds. Ethnobotanically, *M. parvifolia* is important in Ayurveda and Unani medicine for treating fever, wounds, gastrointestinal issues, skin infections, and inflammation (Usha Jadhav et al., 2022). The phytochemical studies reveal active compounds alkaloids, flavonoids, tannins, saponins, glycosides—with anti-inflammatory, antimicrobial, antioxidant, and hepatoprotective effects (Sharma et al., 2019). Economically, the wood is used for furniture and tools; bark for ropes; and leaves as emergency fodder.

Despite its utility, the species faces threats from overharvesting and habitat loss. Conservation through agroforestry, in-situ protection, and nursery cultivation is critical (Patel et al., 2020).To support awareness and conservation, QR codes are being implemented in botanical gardens, trails, and nurseries. They offer instant access to scientific data, uses, cultivation practices, and conservation efforts bridging traditional knowledge with digital tools. This promotes community education, reduces misidentification, and supports sustainable use of *Mitragyna parvifolia.*

The use of QR codes in botanical education enhances user engagement by providing dynamic, multimedia-rich content compared to traditional signboards. Scanning a QR code can instantly connect users to reliable sources such as herbarium databases or research articles, reducing misidentification especially for medicinal plants like *Mitragyna parvifolia*. This technology bridges traditional knowledge with modern tools, promoting digital literacy, conservation awareness, and community empowerment. Overall, the use of QR code technology in documenting and disseminating information about *Mitragyna parvifolia* offers a sustainable, scalable, and inclusive solution for the preservation and responsible use of this highly valuable species.

Materials and Methods

Study Area

The study area was conducted in the Institute of Forest Genetics and Tree Improvement, *Mitragyna parvifolia.*

Data Collection

Extensive field surveys formed the cornerstone of this study, with researchers meticulously documenting *M.parvifolia* populations across their native ecosystems. High-resolution DSLR photography captured critical morphological features, while structured interviews with indigenous communities yielded invaluable ethnobotanical knowledge about the species' traditional applications. These primary findings were cross-verified and enriched through rigorous analysis of seminal botanical works particularly the Presidency of Madras and Flora of Tamil Nadu compendiums.

Fig 1: Botanical Profile, Distribution, and Propagation of *Mitragyna parvifolia*

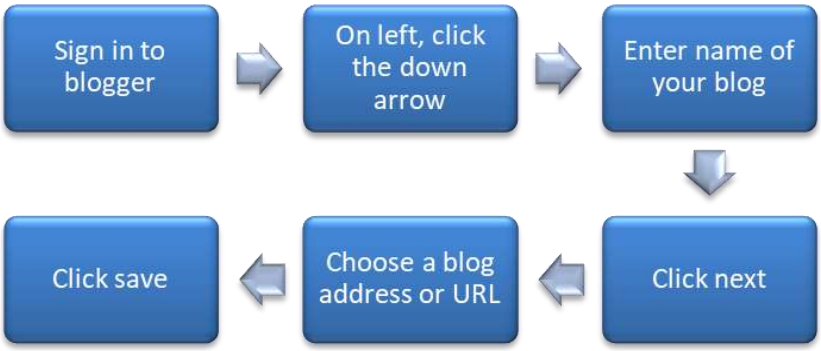
The synthesised data, encompassing taxonomic characteristics, ecological preferences, therapeutic uses, and conservation status, was strategically hosted on a Google-based platform. This innovative digital repository serves multiple critical functions: providing researchers with verified field data, offering conservationists updated distribution patterns, and empowering local communities through accessible ethnobotanical documentation. The platform's dynamic architecture permits real-time updates as new findings emerge, while its cloud-based nature guarantees universal access without geographical or socioeconomic barriers a significant leap forward from conventional static herbarium records.

Plant taxonomy is organized in an integrated database using a botanical taxonomy structure. These plant species databases have been uploaded to Google Drive, and a shareable link has been created for them. To create a rapid response code for a plant species, copy the shareable link into the QR code creator program. We can use a variety of technological gadgets to scan QR codes, such as a tablet or mobile device. The work's process is seen in the screen grab that follows.

Blogger

Blogger is a platform which is owned by Google. The platform is still actively maintained and updated by Google. The blogger is a free web-based blogging platform that allows the users to create and manage their own blogs. Blogger is an American online content management system founded in 1999 which time-stamps entries. Pyra Labs developed the blogger in 1999. Google hosts the blogs, which can be accessed through a subdomain of www.blogger.com.

To create a blog



QR CODE MONKEY

QR Code Monkey is a free online tool that allows users to create custom QR codes. It is

designed for marketers, small businesses, and tech enthusiasts who want to generate personalised and scannable QR codes for various purposes. https://www.qrcode-monkey.com/

QR Code Generation

- ✓ The blog link was processed through **QR Code Monkey**, a free online QR generator.
- ✓ Customisation options (colour, logo embedding) were utilised for aesthetic and branding purposes.
- ✓ The final QR code was downloaded in high resolution for printing on plaques near the tree.

Based on the provided blog content and images from the "Plant-flora". The webpage offers a detailed botanical and ecological overview of *Mitragyna parvifolia* (Roxb.) Korth, locally known as Neer Kadambu, a deciduous tree native to the Indian subcontinent. It belongs to the family Rubiaceae and thrives primarily in regions of Tamil Nadu, as illustrated through distribution maps and images.

Botanical Characteristics:

- ✓ The tree typically reaches a height of 20–25 metres, with a robust, smooth, greyish bark and simple, opposite leaves that are glabrous with reticulate venation.
- ✓ It produces globose inflorescences with greenish-yellow, fragrant flowers, and the reproductive system includes well-defined calyx, corolla, androecium, and gynoecium structures.
- ✓ The fruit is a capsule with winged seeds dispersed by wind (anemochory), and the flowering-fruiting period is from March to August.
- ✓ Pollination is carried out by insects like butterflies, bees, and moths, with butterflies playing a primary role.

Uses and Importance:

- ✓ Medicinally, the bark and leaves are traditionally used for fever, inflammation, and pain relief.
- ✓ Timber from the tree is durable and resistant to termites, making it ideal for furniture and construction.
- ✓ Ecologically, the tree contributes to soil erosion control, habitat provision, and biodiversity support.

Propagation:

- ✓ The plant is primarily propagated through seed germination, with clear visual documentation of stages: sowing, germination (3 weeks to 1 month), and transplantation to polybags.

Implementation Strategy

QR codes were strategically placed near M. parvifolia specimens in botanical gardens and nature reserves, allowing visitors to scan and instantly access detailed information, including the plant's botanical description (morphology, flowering/fruiting cycles), ecological and geographical distribution, traditional medicinal applications (tribal uses and pharmacological potential), as well as its conservation status and guidelines for sustainable utilisation. This interactive approach not only enhanced visitor engagement but also promoted awareness about the species' ecological significance and conservation needs.

Results and Discussion

The integration of QR codes near M. parvifolia specimens offers significant **educational benefits**, providing visitors with instant access to detailed, multimedia-rich information that fosters self-guided learning and deeper engagement with biodiversity. This approach also presents clear **advantages over traditional methods**, such as improved sustainability by reducing paper and plastic waste from conventional signboards, the flexibility to dynamically update content without physical replacements, and multilingual support through digital platforms that broaden accessibility. Furthermore, the system holds promising **potential applications**, including enhancing ecotourism experiences with interactive plant profiles along nature trails, serving as a quick reference tool for researchers in the field, and enabling community involvement by allowing local populations to contribute ethnobotanical knowledge through editable digital platforms. Together, these features create an innovative, inclusive, and eco-friendly way to connect people with plant conservation and education.

Conclusion

The integration of QR codes with botanical information on *Mitragyna parvifolia* presents a cost-effective, scalable solution for environmental education. This approach can be extended to other plant species, fostering greater public interest in biodiversity conservation. Future studies could assess visitor engagement metrics and expand digital content to include augmented reality (AR)features.

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SELF-CLEANING TEXTILES: PRINCIPLES, MAKING ROUTES AND CURRENT DIRECTIONS

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Abstract

Fabrics that stay clean with little or no washing cut water use, energy demand and detergent discharge. Two ideas dominate the field: (i) water-repellent surfaces that let droplets roll off and take dust with them, and (ii) light-driven coatings that oxidise stains on the fibre itself. This concise review explains how those effects are created on cloth, from pad–dry–cure sol–gel finishes to plasma grafting and hydrothermal growth of TiO_2/ZnO nanostructures. Uses now stretch from outdoor jackets to farm workwear, hospital linens and de-icing filters. Research is shifting toward fluorine-free chemistries, tougher nano-textures, and visible-light photocatalysts and life-cycle verified benefits. The key hurdles remain wear resistance, PFAS regulation, nanoparticle release and affordable scale-up.

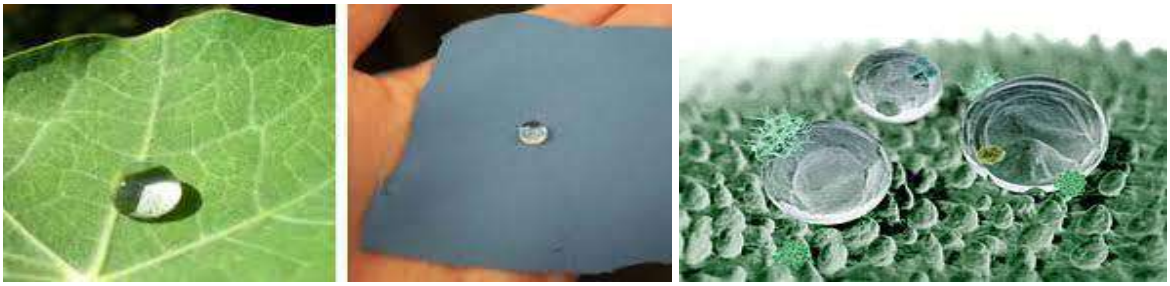
1. Introduction

Domestic laundering typically spends 40–60 L of water per load and releases both surfactants and microfibres. Reducing the number of wash cycles is therefore an obvious sustainability lever. “Self-cleaning” textiles—cloth that either avoids wetting or destroys grime when exposed to light—have moved from lab curiosity to pilot production over the past five years. Here, the focus is on the working physics/chemistry, the finishing methods that can be run on standard textile lines, and where the technology is actually useful.

2. How do fabrics clean themselves?

2.1 Superhydrophobic (physical) cleaning

When a surface is very rough on two length scales and coated with a low-energy layer, water hardly touches it (contact angle >150°, sliding angle a few degrees). Droplets bead, roll and pick up loose particles. Getting this to last on fabric means: build micro/nano texture, attach the chemistry strongly and keep breathability so the garment is comfortable.



Lotus Effect

2.2 Photocatalytic / oxidative cleaning

Oxides such as TiO_2 or ZnO absorb light and form reactive oxygen species that chop up oils, dyes and odour molecules. Doping (e.g., N, Ag) or forming heterojunctions pushes activity into the visible range so indoor light is enough. The catalyst must be fixed firmly to the fibre so it does not wash out.

2.3 Bio-active add-ons

Silver, copper or quaternary ammonium groups suppress bacterial growth and the smells it causes. Many recent papers report triple-function finishes—water repellency + photocatalysis + antimicrobial action—on the same fabric.

3. Making routes (laboratory to mill)

3.1 Pad–dry–cure sol–gel

A liquid sol containing silanes, silica or TiO_2 is padded through the fabric, squeezed to the desired pick-up and cured at 100–150 °C. The method is cheap and familiar to mills; drawbacks include possible stiffness and reliance on PFAS.

3.2 Plasma activation and grafting

Low-pressure or atmospheric plasmas activate fibre surfaces and let organosilicon layers graft without solvents. Plasma also roughens fibres at the nanoscale. The barrier is capital cost, not performance.

3.3 Spray or knife coating of PDMS/silicones

Room-temperature curing silicone dispersions form elastic, low-energy skins and can self-heal minor scratches. Too thick a film, however, hinders moisture vapour transmission.

3.4 In-situ oxide growth

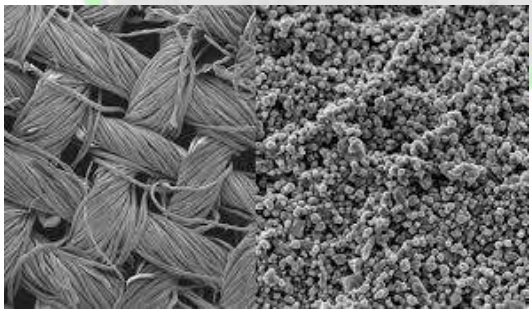
Cotton or polyester can be immersed in hydrothermal baths (≈80–95 °C) that nucleate ZnO/TiO_2 nanorods directly on the fibre, improving wash fastness and cutting nanoparticle release. Multi-step batch processing limits throughput today.

3.5 Electrospun overlays

Nanofibre veils (PU, fluoropolymers, silicones) electrospun onto cloth create the needed dual roughness. They are tunable but slow for wide rolls unless multi-nozzle setups are used.

4. Where are self-cleaning fabrics used?

- Outdoor / sportswear: Rain and mud simply roll off, so garments need fewer washes.
- Agricultural workwear & storage sacks: Treated cotton/jute resists stains and fungal growth, saving groundwater and extending sack life.
- Medical textiles: Photocatalytic drapes and dressings cut microbial load under ward lighting, trimming sterilisation cycles.
- Filters and anti-icing media: Superhydrophobic non-wovens resist icing and fouling; wettability-tuned membranes separate oil from water.
- Protective uniforms: Oil-repellent, flame-retardant blends keep stains off without compromising FR performance when finishes are compatible.



Self-cleaning technology

5. Recent trends

1. PFAS exit strategies: Silicone hybrids, alkylsilanes and bio-based waxes aim to match fluorocarbon durability without persistence issues.
2. Abrasion resistance: Embedding particles inside polymer binders, using elastic/self-healing matrices and designing reflowable coatings help survive laundering and rubbing.

3. Indoor-light photocatalysis: Doped TiO_2, ZnO composites and carbon nitride systems respond to visible light, not just UV.
4. Life-cycle thinking: Studies now compare the saved wash water/energy with the chemical and energy cost of finishing.
5. Multifunctionality and sensing: Coatings that clean, kill microbes and signal contamination (colour change) are emerging.

Conclusion

Self-cleaning textiles can genuinely lower maintenance impacts if finishes last through real wear and washing. The field's success will depend on PFAS-free hydrophobics that breathe, catalysts that work under indoor light, coatings that survive abrasion, and proof—via LCA—that the environmental maths adds up. Scaling these chemistries onto roll-to-roll lines at acceptable cost remains the practical bottleneck, especially for agricultural and healthcare settings where margins are thin.

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THE IMPORTANCE OF HONEYBEES FOR CROP PRODUCTION

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Introduction

Honeybees (Apis mellifera) are widely recognized as essential pollinators, playing a crucial role in the reproductive processes of many plants, particularly in agriculture. Their contribution to crop production is indispensable, not only for the diversity of fruits, vegetables, and nuts but also for the broader economic impact they have on food production worldwide. While honeybees have been domesticated for their honey and wax for thousands of years, their role in pollination is arguably even more significant in sustaining global food security.

This article explores the importance of honeybees for crop production, the mechanisms by which they pollinate plants, the challenges honeybee populations face, and the impact of their decline on agricultural systems. Through understanding the ecological and economic benefits provided by honeybees, this article underscores the critical need to protect these pollinators and ensure their continued role in agricultural productivity.

1. Honeybee Pollination and Crop Production

Pollination is the process by which pollen is transferred from the male part (anther) of a flower to the female part (stigma), enabling fertilization and the production of seeds and fruit. Honeybees, like many other pollinators, move pollen between flowers as they forage for nectar and pollen, inadvertently facilitating plant reproduction. This process is essential for the production of many crops, including fruits, vegetables, nuts, and oilseeds.

1.1. A Key to Food Crop Reproduction

It is estimated that approximately 75% of flowering plants and 35% of global food crops rely on animal-mediated pollination (Klein et al., 2007). Among these, honeybees are the most

efficient and widely used pollinators, especially in agricultural systems. Crops that benefit from honeybee pollination include apples, almonds, blueberries, cucumbers, pumpkins, tomatoes, and many others. The yield and quality of these crops can be directly influenced by the presence of honeybees in the environment.

For example, honeybees are known to be key pollinators of almonds (Prunus dulcis) in California, where approximately 80% of the world's almond supply is produced (Morse & Calderone, 2000). Without honeybees, almond production would not be able to meet current demand, highlighting their irreplaceable role in this and other crop production systems.

1.2. Enhanced Crop Yields and Quality

In addition to increasing the quantity of crops produced, honeybee pollination also improves the quality of the final product. Pollinated flowers often produce better fruit, with larger size, more uniform shape, and improved color. For instance, studies have shown that honeybee-pollinated strawberries are larger and more uniform compared to those pollinated by wind or by other insects (Free, 1993). Furthermore, honeybees contribute to the genetic diversity of plants, which is crucial for the long-term sustainability of agricultural systems. A greater diversity of plant varieties can result in stronger, more resilient crops that are better able to adapt to changing environmental conditions.

2. The Economic Contribution of Honeybees

The economic value of honeybees as pollinators is immense. According to the Food and Agriculture Organization (FAO), it is estimated that the global value of insect pollination is between $235 billion and $577 billion annually (Gallai et al., 2009). Honeybees alone account for a significant portion of this, with their pollination services contributing billions of dollars to global agriculture.

2.1. Agriculture and Pollination Services

In the United States alone, honeybees contribute an estimated $15 billion annually to crop production through pollination services (USDA, 2020). The almond industry in California is one of the most notable examples, where honeybee pollination is vital to ensuring that the flowers of almond trees are fertilized, resulting in high-yield production. Similarly, many fruit and vegetable farmers across the world rely on managed honeybee colonies for pollination, underscoring the economic importance of these insects.

Moreover, honeybees also enhance the productivity of non-food crops like cotton, which benefits from pollination for better seed production. In essence, honeybees directly or indirectly influence the success of a wide range of crops, which supports farmers' incomes, creates jobs in rural areas, and strengthens local economies. Honeybee pollination also has downstream effects, stimulating related industries such as food processing, transportation, and retail.

2.2. Global Trade and Food Security

The decline of honeybee populations poses a significant risk to global food security. As the availability of pollinated crops decreases, both the price and availability of fruits, vegetables, and other key agricultural products will be affected. For regions heavily dependent on pollinator-dependent crops for export, such as almonds in the United States and coffee in Central America, reduced pollination can result in economic losses and reduced global trade opportunities.

Thus, maintaining healthy honeybee populations is not just an issue for farmers—it has far-reaching implications for global trade, food prices, and the availability of diverse diets. The loss of honeybees would exacerbate existing challenges in food distribution and access, especially for vulnerable populations in developing countries.

3. Challenges Facing Honeybee Populations

Despite their importance, honeybee populations have been facing significant challenges in recent decades. These challenges are compounded by multiple stressors, including habitat loss, pesticide exposure, diseases, and climate change.

3.1. Pesticides and Chemical Exposure

One of the most significant threats to honeybees is the widespread use of pesticides in agriculture. Neonicotinoids, a class of systemic insecticides, have been linked to colony collapse disorder (CCD), a phenomenon where entire honeybee colonies die or disappear. These chemicals affect the bees' navigation abilities, immune systems, and reproductive health, making them more susceptible to diseases and environmental stressors (Gill et al., 2012). The direct exposure to pesticides during foraging and the accumulation of these chemicals in the hive can disrupt hive function and lead to colony collapse.

3.2. Habitat Loss and Fragmentation

As agricultural landscapes become more industrialized, honeybees are losing access to natural habitats that provide diverse forage and nesting sites. The expansion of monoculture farming, while economically efficient, reduces the variety of plants that honeybees rely on for

nectar and pollen. Habitat fragmentation, urbanization, and land-use changes further exacerbate the loss of suitable foraging grounds. This lack of biodiversity in agricultural environments limits the nutritional diversity of honeybees' diets, contributing to weakened immune systems and reduced resilience.

3.3. Diseases and Parasites

Honeybees are also vulnerable to diseases and parasites, which can devastate entire colonies. The Varroa destructor mite, in particular, has been one of the most destructive pests, feeding on honeybee larvae and spreading viruses that weaken colonies. Infected colonies may become too weak to survive through the winter, leading to widespread losses. Other pathogens, including Nosema, a fungal infection that affects the digestive systems of honeybees, also contribute to colony decline (Fries, 2010).

3.4. Climate Change

Climate change is another major threat to honeybee populations. Rising temperatures, altered rainfall patterns, and changing flowering times can disrupt the timing of plant-pollinator interactions. Climate change may cause plants to bloom earlier or later than normal, creating mismatches between when flowers are available and when bees are most active. Additionally, extreme weather events, such as floods or droughts, can destroy bee habitats and reduce the availability of forage plants.

4. Protecting Honeybees: Strategies and Solutions

To safeguard honeybee populations and ensure their continued role in crop production, several strategies can be implemented.

4.1. Reducing Pesticide Use

Farmers and policymakers can work together to reduce the use of harmful pesticides, particularly neonicotinoids. Integrated pest management (IPM) approaches, which combine biological controls, crop rotation, and selective pesticide use, can help reduce the dependency on chemical pesticides. Furthermore, establishing buffer zones around pollinator habitats can protect bees from pesticide exposure.

4.2. Enhancing Pollinator Habitats

Creating pollinator-friendly environments is essential to support honeybee populations. This can be achieved through habitat restoration, planting diverse wildflowers, and preserving hedgerows and natural areas that provide food and nesting sites for honeybees. Additionally,

offering farmers incentives to plant pollinator strips or cover crops can help enhance biodiversity and support the health of honeybee colonies.

4.3. Supporting Research and Monitoring

Ongoing research into honeybee health, behavior, and ecology is crucial for understanding the challenges they face. Monitoring bee populations and tracking the spread of diseases and parasites can help inform management practices and early interventions to prevent widespread colony losses.

4.4. Climate Change Mitigation

Efforts to mitigate climate change, such as reducing greenhouse gas emissions and promoting sustainable farming practices, can help protect honeybees by stabilizing ecosystems and preventing extreme weather events that disrupt their habitats. Adapting farming practices to be more climate-resilient will ensure the availability of forage and nesting sites for honeybees, even in the face of climate change.

Conclusion

Honeybees are indispensable to global agriculture, serving as the primary pollinators of many crops that are essential to food production. Their role in increasing crop yields, improving quality, and enhancing food security cannot be overstated. However, honeybees are facing numerous challenges, including pesticide exposure, habitat loss, diseases, and the effects of climate change. It is imperative that concerted efforts are made to protect and support honeybee populations through sustainable farming practices, habitat restoration, and research into pollinator health. By safeguarding honeybees, we are not only protecting a vital ecosystem service but also ensuring the continued availability of diverse and nutritious food for generations to come.

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THE NATURE'S ELIXIR - ROYAL JELLY AND IT'S HEALTH BENEFITS

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Abstract

Royal jelly is a kind of bee product widely used in cosmetics, medicine and other fields. Not only can Royal jelly regulate the physiological function of bee population, but also play a specific biological role in many diseases. The active role of Royal jelly in the maintenance of human health, such as the regulation of immunity, lifespan, memory, digestive system, blood glucose, obesity, antibacterial and anti-cancer effect, among which the regulation of memory can be used in the treatment of Alzheimer's disease. These findings will benefit for comprehensive understanding and use of Royal jelly. Hence making it more effective in maintaining health.

Key words: Royal jelly, Active components, Biological functions

Introduction

Royal jelly is often referred to as a honey bee's version of "a mother's milk" and is a protein-rich secretion produced by worker bees. This milky substance is fed to all larvae for a short period of time during the honey bee life cycle, and is also fed to the developing queen bee in extra amounts. Royal jelly is Secreted by hypopharyngeal gland of young nurse and an exclusive nourishment for bee queen, has been used since ancient times for care and human health and it is still very important in traditional medicine, especially in Asia within the apitherapy. Royal jelly and its protein and lipid components have been subjected to several investigations on their antimicrobial activity due to extensive traditional uses and for a future application in medicine (Brittany schmus *et al*. 2022).

Royal jelly

Common names for royal jelly include Bee Saliva, Bee Spit, Honey Bee Milk, Royal Bee Jelly, Gelee royale, Lait des Abeille's. Honey bees are incredibly fascinating and resourceful creatures, and the production of royal jelly is just one of the many awe-inspiring things that a worker bee can do. Royal jelly is something that is naturally produced by nurse bees that are six to 14 days old.

Royal Jelly is a glandular secretion white-yellowish gelatinous-viscous sour taste, with a slight characteristic smell of phenol produced from the hypopharyngeal and mandibular salivary glands of young nurse. During the process of creating new queens, the workers construct special queen cells. The larvae in these cells are fed with copious amounts of royal jelly. This type of feeding in part triggers the development of queen morphology, including the fully developed ovaries needed to lay eggs (Brittany schmus *et al*. 2022).

Components of royal jelly:

- **Water (~60–70%)**

  It Makes up the majority of royal jelly, giving it a gel-like consistency.

- **Proteins (~9–18%)**

Major Royal Jelly Proteins (MRJPs) – a unique group of proteins, especially MRJP1 to MRJP5.These proteins are crucial for the development of the queen bee and may have antimicrobial and immune-boosting properties.

- **Sugars (~7–18%)**

Mainly consists of fructose and glucose. It Provides energy, similar to honey, but in lower concentration.

- **Lipids (Fats) (~3–8%)**

Includes unique medium-chain fatty acids, especially 10-Hydroxy-2-decenoic acid (10-HDA) a key bioactive compound only found in royal jelly.Sebacic acid and other hydroxy fatty acids with antibacterial and anti-inflammatory properties.

- **Vitamins**

Especially high in B-complex vitamins; B5 (Pantothenic acid) ,B6 (Pyridoxine),B1, B2,

B3, B7 (Biotin), B9 (Folate) Trace amounts of vitamin C (no fat-soluble vitamins like A, D, E, K) (Filippo *et al*., 2016).

- **Minerals and Trace Elements**

  Calcium, potassium, magnesium, zinc, iron, manganese, sodium, and copper.

- **Enzymes**

  It includes glucose oxidase and others that may help preserve and protect the jelly.

- **Amino Acids**

  Both essential and non-essential amino acids. Especially rich in proline, lysine, and arginine.

- **Hormonal Substances (Trace)**

  Contains small amounts of estrogenic-like compounds and acetylcholine (a neurotransmitter), which may influence fertility and brain function.

Health benefits of royal jelly uses in human being:

1. Cognitive and Mental Health Support

May help with memory, learning, and neuroprotection because it is rich in Contains acetylcholine (a neurotransmitter) and antioxidants.

2. Immune System Boost

Supports immune function and helps fight infections since it is rich in proteins (MRJPs), vitamins, and 10-HDA with antimicrobial effects.

3. Cardiovascular Health

Lowers cholesterol and improve blood pressure.

4. Anti-Inflammatory & Antioxidant Effects

Reduces inflammation and oxidative because it is rich in phenolic compounds and fatty acids like 10-HAD.

5. Wound Healing

Royal jelly has also been explored for its wound-healing properties. Its antimicrobial and anti-inflammatory properties may promote faster healing of wounds and burns when applied topically (Jayapal *et al*., 2024)

6. Menopausal and PMS Symptom Relief

May reduce hot flashes, mood swings, and fatigue. It also has Possible hormonal effects and support for estrogenic regulation.

7. Fertility and Reproductive Health

May support fertility in both men and women as it Contains trace hormones and nutrient compounds affecting reproductive health.

8. Nutritional Supplement

Taken in small daily doses for general wellness, energy, and vitality in forms of fresh royal jelly, capsules, powders, or mixed with honey.

Other uses of royal jelly:

Since the royal jelly is a rich source of nutrient and other growth promoting substances, it is being used in different preparations. With the time, many new uses of this product have been reported.

A) Cosmetics and Medicines

The largest use of royal jelly has been in cosmetic sector. Royal jelly is used in many dermatological preparations. These are mostly used for skin refreshing and skin rejuvenation. It is also used in cream or ointments which is used for healing of burns and other wounds.

B) Supplement to the Normal Diet

The royal jelly being nutritious may be consumed along with other food stuffs. The royal jelly may supply a particular nutrient which may be absent in the food.

Conclusion

Royal jelly, a secretion from worker bees, is a promising natural substance with a range of potential health benefits and applications. While it shows promise in areas like wound healing, immune function, and menopausal symptom relief, more research is needed to fully understand its effects and establish optimal dosages. It also has demonstrated much nutritional benefits such as antibacterial, antitumor, and anti-aging.

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SUSTAINABLE AGRICULTURE FOR ZERO HUNGER

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Abstract

Sustainable agriculture is a smart way of farming that helps grow enough food without harming the environment or future generations. It uses natural resources like water and soil carefully and supports farmers, especially small ones, to earn a better living. By using methods like organic farming, crop rotation, and saving water, we can produce healthy food for everyone. New ideas like using technology in farming, growing food in cities, and reducing food waste also help fight hunger. Some places, like Sikkim in India, have shown great success with these methods. Even though there are problems like lack of knowledge, high costs, and poor access to tools, we can overcome them with good policies, training, and teamwork. Sustainable agriculture is a key solution to ending hunger and building a better future for all.

KEY WORDS

Sustainable agriculture, Zero hunger, Organic farming, Crop rotation, Water conservation

Introduction

Sustainable agriculture plays a vital role in achieving zero hunger by producing enough food in an environmentally, friendly and socially responsible way. It focuses on using natural resources efficiently, protecting soil and water, reducing pollution, and supporting farmers livelihoods. By promoting practices like crop rotation, organic farming, and water

conservation, sustainable agriculture ensures that current and future generations have access to safe, nutritious, and sufficient food.

WHAT IS SUSTAINABLE AGRICULTURE?

Sustainable agriculture is an approach to farming that ensures food production can continue indefinitely without causing environmental degradation or harming future generations. It integrates three main objectives: Environmental health (soil, water, and biodiversity conservation),Economic profitability (viable income for farmers),Social and food equity (access to nutritious food and fair livelihoods)

It encourages methods like:

- Organic farming
- Crop rotation and diversification
- Agroforestry
- Conservation tillage
- Efficient water management
- Use of renewable energy in farming.

SUSTAINABLE AGRICULTURE STRATEGIES FOR ACHIEVING ZERO HUNGER

Sustainable agriculture helps us grow enough food without harming the environment. To end hunger, farmers can use better seeds that grow well even without much water. They can also use less water by using drip irrigation and collecting rainwater. Natural ways of farming, like using compost instead of chemicals, keep the soil healthy. Teaching farmers new methods and giving them fair prices helps them grow more food. We should also stop wasting food and eat in a balanced way. These simple steps can help make sure everyone has enough healthy food to eat.

- **WATER MANAGEMENT:**

Implementing efficient irrigation systems, rainwater harvesting, and water conservation practices to ensure sustainable water use in agriculture. Proper water management is essential for crop production and food security.

- **USE OF ORGANIC INPUTS:**

Emphasizing the use of organic fertilizers, compost, and biopesticides to improve soil health, reduce chemical inputs, and protect biodiversity. Organic farming practices

promote long-term sustainability and support ecosystem health.

- **CROP DIVERSIFICATION:**

Encouraging the cultivation of a variety of crops to improve nutrition, enhance resilience to pests and diseases, and promote ecosystem balance.

Diversified farming systems can ensure food security and livelihoods for small-scale farmers.

HOW SUSTAINABLE AGRICULTURE SUPPORTS ZERO HUNGER:

1. *Increases Food Production*

Sustainable practices like crop rotation, organic farming, and integrated pest management help improve soil health and increase crop yields without harming the environment. This ensures a steady and long-term supply of food for all.

2. *Protects Natural Resources*

Techniques such as water conservation, reduced chemical use, and soil management protect key resources like water, land, and biodiversity, which are essential for growing food now and in the future.

3. *Supports Small-Scale Farmers*

Sustainable agriculture often emphasizes local knowledge and low-cost methods, helping smallholder and family farmers improve productivity and income. This empowers rural communities and reduces poverty and hunger.

4. *Reduces Food Waste and Loss*

Post-harvest techniques, better storage, and local distribution help reduce the loss of food between farms and markets, ensuring more food reaches consumers.

5. *Adapts to Climate Change*

Sustainable agriculture builds resilience by promoting crops and practices suited to local climate conditions, helping farmers adapt to changing weather patterns and reduce risk.

INNOVATIONS AND SOLUTIONS TOWARD ZERO HUNGER:

1. **Improved Agricultural Techniques**: Enhancing agricultural practices through precision farming, sustainable farming methods, and use of advanced technologies such as drones and sensors can increase crop yields and food production

2. **Biotechnology and Genetic Engineering**: Research on genetically modified crops that are more resistant to pests, diseases, and environmental stress can lead to higher yields and better nutrition.
3. **Food Waste Reduction**: Implementing strategies to reduce food waste in production, distribution, and consumption can help maximize food availability for those in need
4. **Support for Small-scale Farmers**: Providing small-scale farmers with access to resources, training, and technology can help them improve productivity and income, contributing to food security.
5. **Urban Agriculture**: Promoting urban agriculture initiatives such as rooftop gardens and community gardens can increase access to fresh produce in urban areas.

REAL WORLD EXAMPLES:

- **Sikkim, India**: Became the first 100% organic state, increasing farmer incomes and biodiversity.
- **System of Rice Intensification (SRI)**: Farmers in Asia and Africa have reported 20–50% yield increases using less water and seeds.
- **Agroecology in West Africa**: Improved food security while promoting gender equity and land conservation.

CHALLENGES TO IMPLEMENTATIONS:

- Lack of Awareness and Education
- High Initial Costs
- Limited Access to Resources
- Lack of Government Support
- Climate Change
- Market Problems
- Lack of Technology

SOLUTION TO IMPROVE SUSTAINABLE AGRICULTURE:

- **Policy support:** Incentives for organic inputs, crop insurance, and sustainable certifications.

- **Technology transfer:** Dissemination of low-cost, eco-friendly innovations to rural areas.
- **Education and training:** Extension services to promote sustainable practices.
- **Public–private partnerships:** Mobilizing funds and infrastructure for scaling sustainable farming**.**

Conclusion

Sustainable agriculture is very important to end hunger in the world. It helps us grow enough food in a way that protects nature, saves water, and keeps the soil healthy. It also helps small farmers earn more and gives people better, safer food. By using smart farming methods, reducing waste, and working together, we can make sure that everyone gets enough healthy food today and in the future. Sustainable agriculture is the key to building a hunger-free and healthy world.

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COMMUNICATION IN HONEY BEES

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Abstract

Honey bees use many different ways to talk to each other, such as smells (pheromones), touch, sounds, and dances. These signals help them work together to find food, protect the hive, raise young, and even move to new homes. Bees can also change how they communicate depending on their environment, like when there is less food or more danger. Studying how bees communicate helps us understand how social animals live and how bees support nature through pollination.

Key words:

Honey bee communication, Waggle dance, round dance, Pheromones, Queen pheromone, Alarm pheromone, Human impact, Trophallaxis, Colony organization

Introduction

Honey bees live in large, organized groups called colonies, and communication is what keeps them working together. They use chemical smells, physical contact, and behaviours like dancing to share information. One of the most famous discoveries about bees is the waggle dance, which tells other bees where to find food. Scientists have since learned more about the sounds and smells bees use too. But changes caused by humans—like pollution and habitat loss—may be affecting how bees communicate. This article explains the different ways bees communicate, why it matters, and what we still need to learn.

1. **How Honey Bees Communicate**

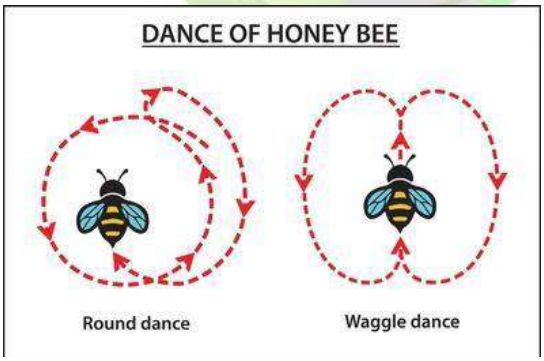
https://www.earth.com/news/bee-communication-is-hindered-by-human-activity/

Bees have several ways to send messages inside the hive:

- **Smells (Pheromones)**: Bees use special smells to signal things like danger, the presence of a queen, or when babies need care. Queen bees produce a scent that keeps worker bees from laying eggs.
- **Touch and Taste (Trophallaxis)**: Bees feed each other by mouth, and during this process, they also share chemical signals that help pass along information.
- **Sight and Movement**: Bees use the waggle dance to show the direction and distance to food. The way a bee moves its body gives clues to the location.
- **Sound and Vibration**: Bees make buzzing sounds or shake their bodies to encourage others to forage or to send warnings.

These methods often work together to make sure the message is clear.

2. **Bee Dances: Round and Waggle**



https://www.shutterstock.com/search/waggle-dance?dd_referrer=https%3A%2F%2Fwww.google.com%2F

- **Round Dance**: Bees do this dance when food is close to the hive (within 100 meters). It tells other bees, "There is food nearby," but doesn't give a direction.
- **Waggle Dance**: Used for food that is farther away. The bee moves in a figure-eight

pattern. The direction of the "waggle" part shows where the food is in relation to the sun, and how long the waggle lasts tells how far it is. Bees also use smells and vibrations during the dance to make the message stronger.

Different honey bee species have slight differences in how they perform these dances.

3. **Pheromones and Hive Control**

https://wildflowermeadows.com/2017/08/queen-pheromone/

- **Queen Pheromone**: The queen bee produces a mix of scents that tell the colony she's healthy and in control. If she dies or is removed, the workers notice and begin raising a new queen.
- **Alarm Pheromone**: When bees sting, they release a scent like bananas (isopentyl acetate) that tells others to prepare for defence.
- **Nasonov Pheromone**: Smells like lemongrass and helps bees find the hive or stay together during swarming.
- **Brood Pheromone**: Baby bees produce a scent that tells nurse bees how much and what kind of food they need. Unfortunately, harmful mites like Varroa can also detect this smell and use it to find baby bees to infest.

4. Warning and Defence Signals

- **Alarm Pheromone**: Released when bees feel threatened. It calls other bees to help defend the hive.
- **Stop Signal**: If a bee finds danger near a food source, it will head-butt a dancing bee and make a short buzz. This makes the dancer stop recruiting others to the dangerous spot.
- **Aggressive Behaviour**: In fights between bees from different colonies, bees may bite or bump into each other. Surprisingly, smaller species often win by recruiting more helpers faster.

5. How Communication Evolved and What Affects It

- **Colony Size and Nest Type**: Big colonies like those of honey bees need detailed communication like dances. Smaller ones like bumble bees often rely on simpler signals.
- **Nest Environment**: Bees that live in open spaces can use the sun to guide their dances. Bees in enclosed nests rely more on gravity and internal cues.
- **Food and Environment**: In rich environments like tropical forests, it's helpful to share exact food locations. In places with scattered food, bees may do better searching on their own.
- **Human Impact**: Pesticides, climate change, and habitat loss can damage how bees see, smell, and move, making it harder for them to communicate properly.

6. What We Still Don't Know

- **Mysteries in Stingless Bees**: Some bees find and share food without clear dances or scent trails. Scientists think they may use smell trails in the air or follow each other visually, but this needs more research.
- **Stop Signals and Feedback**: Bees use both "go" and "stop" messages, like machines that balance signals. Studying this helps us learn about how groups make decisions together.
- **How the Waggle Dance Began**: Only honey bees do the full waggle dance. Scientists are still figuring out how and why this unique skill evolved.

Conclusion

Bees use many smart ways to talk to each other—using smells, movements, touch, and sound—to keep their colonies running. These behaviours have developed over time to help them survive and work together. But things like pollution, pesticides, and climate change are making it harder for bees to share information. Understanding how bees communicate helps us protect them and the plants they help pollinate. Saving bee communication is not just about bees—it's about keeping nature in balance

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BIODEGRADABLE PLASTICS: A LEAP TOWARDS A SUSTAINABLE FUTURE

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Introduction

Do you remember when you last threw out a plastic cover? Have you ever thought about where it is going to end up? Maybe the answer is 'NO'. The widespread use of conventional petroleum-based plastics has resulted in an alarming accumulation of waste in our oceans, landfills, and even within our bodies through microplastics. Plastic pollution has become a growing global crisis with far-reaching consequences for ecosystems, wildlife, and human health. Every year, over 400 million tonnes of plastic are produced globally—and less than 10% of it is effectively recycled. The rest often ends up as pollution.

But wait, what can we actually do now? We can't just stop using plastics completely, and even reusing them has its limitations. Recycling is not always economical, efficient, or widely practiced. Additionally, plastics can't be entirely replaced by paper, metals, or glass due to their unique properties like flexibility, strength, and moisture resistance.

So, what's the solution?

Here comes our hero: **Biodegradable Plastics**. These are a class of materials engineered to break down into harmless byproducts—such as carbon dioxide, methane (under anaerobic conditions), water, and biomass—under the right environmental conditions. Unlike ordinary

plastics that can persist unchanged for hundreds of years, these materials are designed to decompose through microbial action. However, the rate and extent of degradation depend on various factors, including the polymer's chemical structure, ambient temperature, humidity, availability of oxygen, microbial activity, and the presence of additives that may influence the biodegradation process.

Clearing Common Misconceptions

Not all "bio-based" plastics are biodegradable, and not all "biodegradable" plastics are bio-based. For instance, a plastic made from corn or sugarcane may resist microbial breakdown, whereas a petroleum-derived polymer could be designed to biodegrade rapidly. Therefore, it is essential to look for **certified compostability marks**, such as **ASTM D6400**, **EN 13432**, or **IS/ISO 17088** in India, to verify environmental friendliness. A "green" label alone is not sufficient proof of eco-compatibility.

A Brief History and Evolution of Biodegradable Plastics

The concept of biodegradable materials is older than many might assume. The **first man-made bioplastic**, **Parkesine**, was created in 1862 by Alexander Parkes using cellulose. Although it was not biodegradable by modern standards, it signaled the beginning of bio-derived materials. In 1926, **Maurice Lemoigne** discovered **polyhydroxybutyrate (PHB)**—a biopolymer naturally produced by bacteria.

It wasn't until the **1970s**, amid growing environmental concerns and the energy crisis, that serious efforts were made to develop biodegradable formulations. Since then, advances in biotechnology, polymer science, and environmental regulations have driven innovations in biodegradable plastic materials.

Classification and Characteristics of Modern Biodegradable Plastics

Modern biodegradable plastics fall into two main categories:

1. Bio-based and Biodegradable Plastics

- Derived from renewable resources such as corn, sugarcane, potatoes, and cassava.
- Examples: PLA (Polylactic Acid), PHAs (Polyhydroxyalkanoates), and starch blends.

2. Petroleum-based and Biodegradable Plastics

- Synthesized from fossil fuels but engineered to degrade under composting conditions.
- Examples: PBAT (Polybutylene Adipate Terephthalate), PCL (Polycaprolactone).

Major Types:

- **Starch-based Plastics**: Blended with other biodegradable polymers to enhance performance. These are widely used in compostable grocery bags and food service ware.
- **Polylactic Acid (PLA)**: Derived from the fermentation of plant sugars. It's one of the most commonly used biodegradable plastics, ideal for disposable cutlery, packaging, and 3D printing. PLA is industrially compostable but breaks down slowly in landfills or marine environments.
- **Polyhydroxyalkanoates (PHAs)**: Microbially synthesized and fully biodegradable in a variety of environments—including marine ecosystems—making them a strong candidate for replacing plastic in high-risk pollution sectors.
- **Polybutylene Adipate Terephthalate (PBAT)**: Though fossil-fuel based, PBAT is biodegradable and often used in flexible films. It's commonly blended with PLA or starch.

Mechanisms of Biodegradation

The biodegradation of plastics involves both **biotic** and **abiotic** processes:

1. Enzymatic Hydrolysis

Microorganisms release enzymes that break polymer chains into smaller oligomers and monomers.

2. Microbial Assimilation

These smaller units are taken up and metabolized by microbes, eventually releasing **CO_2, water, methane**, and **biomass**.

3. Abiotic Factors

External agents like **heat**, **UV radiation**, **moisture**, and **pH** can fragment plastic chains, enhancing their susceptibility to microbial attack.

Environmental Benefits of Biodegradable Plastics

- **Reduced long-term persistence** in natural environments.
- Lower likelihood of creating harmful microplastics.
- Can be industrially composted into useful organic matter, closing the material loop.
- Potential to reduce **greenhouse gas emissions** when derived from renewable sources.
- Compatible with circular economy principles when designed for **composting or anaerobic digestion**.

Regulation and Standards

Various national and international standards regulate biodegradable plastics:

- **India**: The Plastic Waste Management Rules, 2016 (amended in 2021), mandate certification from the **CPCB** (Central Pollution Control Board) for compostable plastic products.

The **Plastic Waste Management Rules (PWM Rules)** were introduced by the **Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India**, in 2016, and later amended in **2021** to further strengthen the regulation of plastic waste and encourage sustainable alternatives.

I. Compostable Plastics: Mandatory Certification

Under **Rule 4** and **Rule 10** of the PWM Rules:

1. **Only certified compostable plastics** can be manufactured, imported, sold, or used in India.
2. Compostable plastic products **must be approved and certified by the CPCB** (Central Pollution Control Board).
3. Products **must carry a label**, declaring:
    - "**Compostable**"
    - The **certification number** issued by CPCB
    - The **manufacturer's name and registration**

Steps Required for CPCB Certification (for manufacturers or importers):

1. **Application Submission** to CPCB through its **online portal**.
2. **Submission of test reports** from **CPCB-recognized laboratories**, which evaluate:
    - Biodegradability (as per IS/ISO 17088)
    - Disintegration under composting conditions
    - Absence of heavy metals and ecotoxicity
3. **Review and Approval** by CPCB.
4. **Granting of a certificate**, which is valid for **a specific duration** (usually 2 years, renewable).
5. Mandatory **printing of certification number** on each compostable plastic product.

Relevant Indian Standard:IS/ISO 17088:2008

"Specifications for Compostable Plastics"

This standard outlines the testing methods and criteria to determine whether a plastic product is truly compostable under aerobic conditions.

II. Europe: EN 13432 for packaging.

EN 13432 is the **European Union's official standard** that defines the **requirements for packaging recoverable through composting and biodegradation**. It ensures that **biodegradable packaging materials** safely break down in **industrial composting facilities** and do **not harm the environment**.

This standard is especially important for **certifying compostable plastics, films, and packaging materials** in the European market.

Key Requirements of EN 13432

EN 13432 specifies four main criteria that **a packaging material must meet to be labeled as "compostable":**

1. **Biodegradability**
   - **Definition**: Conversion of the material into **CO_2, water, and biomass** by microbial activity.
   - **Requirement**: At least **90% biodegradation within 6 months** under industrial composting conditions ($58 \pm 2°C$).
2. **Disintegration**
   - **Definition**: Physical fragmentation of the material during composting.
   - **Requirement**: After **12 weeks**, **no more than 10%** of the original material should remain above a **2 mm sieve**.
3. **No Adverse Effect on Compost Quality (Ecotoxicity)**
   - **Requirement**: The composted material must **not negatively affect plant growth** or soil quality.
   - **Test**: **Germination tests** are done on plants like cress or barley using compost containing the material.
4. **Low Heavy Metal Content**
   - Packaging must have **safe levels of heavy metals**, such as:
     - Lead (Pb)
     - Cadmium (Cd)
     - Mercury (Hg)

- Hexavalent Chromium (Cr VI)
- Copper (Cu), Zinc (Zn), Nickel (Ni), etc.

These must be within **specified limits** to avoid soil contamination.

III. USA: ASTM D6400 and D6868 for compost ability.

ASTM D6400 and **ASTM D6868** are two important standards developed by ASTM International (formerly known as the American Society for Testing and Materials) that define the **compostability** of plastic products and materials. These standards help ensure that products labeled as **"compostable"** truly break down under composting conditions and do not leave behind toxic residues or harmful fragments.

ASTM D6400: Standard Specification for Compostable Plastics

This is the **most widely recognized** standard for labeling plastics and plastic products as **compostable in municipal or industrial aerobic composting facilities**.

Key Criteria:

1. **Biodegradation**: The material must biodegrade (convert to carbon dioxide, water, and biomass) by at least **90% within 180 days** under controlled composting conditions (usually at 58°C ± 2°C).
2. **Disintegration**: The plastic must **physically break down** into small pieces indistinguishable from the compost within 12 weeks (no more than 10% of original material should remain on a 2 mm sieve).
3. **No Toxic Residues**: The resulting compost must **not harm plant growth**—tested via ecotoxicity tests such as germination and biomass production.
4. **Heavy Metals & Fluorine Limits**: The material must not exceed maximum allowable concentrations of heavy metals like lead, cadmium, mercury, and others.

 ASTM D6868: Standard Specification for Compostable Plastics Used as Coatings

This standard applies to **paper and other compostable substrates** coated with a **compostable plastic film** (like PLA coatings on paper cups or plates).

Key Criteria:

- The **plastic coating** and the **entire product** must meet the **same biodegradation and disintegration standards** as in ASTM D6400.
- Ensures that **coated paper products** (like food containers, wrappers, or cups) do not contaminate composting systems.

Labeling must not mislead consumers. Products labeled as "biodegradable" or "compostable" without meeting specified conditions or certifications are banned in many regions.

Applications in Daily Life

Ever used a biodegradable plastic? You probably have, knowingly or unknowingly. Common applications include:

- **Packaging**: Grocery bags, mailer films, produce packaging, etc.
- **Food Service**: Disposable plates, straws, trays, cutlery.
- **Agriculture**: Mulch films that break down in the field, eliminating collection costs.
- **Medical Field**: Controlled drug release systems, absorbable sutures, implants.
- **Sanitary Products**: Compostable diaper linings, sanitary pads.

Challenges and Limitations

Despite the advantages, biodegradable plastics are not without issues:

- **Higher Cost**: Production is more expensive than conventional plastics.
- **Mechanical Limitations**: May lack strength, flexibility, or barrier properties needed for certain applications.
- **Limited Composting Infrastructure**: Most materials need industrial composting facilities (high temp, moisture, microbial concentration).
- **Risk of Misuse**: Without public awareness, biodegradable plastics may be disposed of incorrectly—landfills and oceans are not effective biodegradation environments.

Future Directions and Innovations

Researchers are exploring:

- **PLA blends** with enhanced durability and flexibility.
- **Enzyme-embedded plastics** that degrade automatically when exposed to certain stimuli.
- **Genetically engineered microbes** that produce PHAs more economically.
- **Hybrid materials** that combine biodegradability with recyclability.

Policy advancements, **subsidies**, and **public education** will be critical to accelerating the adoption of these materials.

Silicone as an Alternative: Durable and Reusable

While **not biodegradable**, **silicone** is gaining ground as an alternative to disposable plastics in kitchen and lifestyle products due to its:

- Durability

- Flexibility
- Heat resistance
- Reusability
- Chemical stability

For kitchen use, ensure silicone products are **food-grade**, **BPA-free**, and **not overheated** for long periods. Silicone is ideal for reusable baking mats, baby products, and storage containers—where biodegradability is less important than reusability.

Conclusion

To conclude, biodegradable plastics may not yet be a perfect or universal substitute for conventional plastics. However, when integrated thoughtfully into our material economy—supported by consumer education, smart regulation, and appropriate waste processing infrastructure—they can play a **transformative role** in mitigating plastic pollution. Combined with strategies like **reuse**, **recycling**, and **alternative materials** like silicone, biodegradable plastics can help lead the way toward a truly **sustainable future** where materials work with nature, not against it.

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DISINFECTION AND HYGIENE IN SILKWORM REARING

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Introduction

One of the major reasons for crop losses in cocoon production is the diseases of silkworms. Proper disinfection of rearing house, its surroundings and appliances and maintenance of hygiene are important to prevent diseases. Diseased silkworms extrude pathogens into the rearing environment that become the source of infection. Destruction of disease causing pathogens is called disinfection. Although it can be done by various methods, the most effective one is chemical method using chemical disinfectants.

Disinfectants recommended in sericulture

- 2% Bleaching powder in 0.3% slaked lime solution
- 2.5% Sanitech/Serichlor in 0.5% slaked lime solution
- 1.25% Sanitech Super in 0.5% slaked lime solution
- 0.05% Asthra solution
- 0.2% Serifit solution
- 0.3% Slaked lime solution (for optional disinfection)
- 10% Formalin solution (for of Rotary mountages)

Requirement of disinfectants

1.5 L/sq. m floor area or

140 ml/ sq. ft. floor area

+ 10% in case of shoot rearing for disinfecting area surrounding rearing house

+ 35% in case of tray rearing for disinfecting rearing trays

Preparation of disinfectants formulations

A. 2% Bleaching powder in 0.3% slaked lime solution (100L)

Ingredients	**Qty. required**
Bleaching powder	2 kg
Slaked lime	300 g
water	100 L

B. 2.5% of Sanitech/Serichlore or 1.25% Sanitech super in 0.5% slaked lime solution (100L)

Ingredients	**Qty.**	**Ingredients**	**Qty.**
Sanitech/Serichlore	2.5L	Sanitech super	1.25
Activator crystals	250g	Activator crystals	125g
Slaked lime	500g	Slaked lime	500g
Water	97.5L	Water	98.75L

C. 0.05% Asthra solution

Dissolve 50 g of Asthra powder in 100 liters of water. Keep the solution for 2 hours before spraying.

D. 0.2% Serifit Solution

Dissolve 200 g of Serifit powder in 100 liters of water. Keep the solution for 30 min. before spraying.

E. 0.3% Slaked lime solution

100 liters of 0.3% slaked lime solution is prepared by mixing 300 g of slaked lime powder in 100 liters of water.

F. 10% Formalin solution

10% formalin solution is prepared by mixing one part of fomalin with 3 parts of water.

Schedule of disinfection

Day	Activity
On completion of rearing	1. Collect and burn diseased larvae, melted/flimsy cocoons 2. Disinfect the Rotary mountages by fumigation with formalin 3. Conduct first disinfection of rearing house and appliances
5 days before brushing	4. Clean and wash the appliances 5. Sun dry the appliances
4 days before brushing	6. Disinfect rearing house with 0.3% slaked lime solution (optional)
3 days before brushing	7. Conduct 2nd disinfection of rearing house and appliances
2 days before brushing	8. Dust 5% bleaching powder & slaked lime mixture around the rearing house 9. Open the windows of rearing house for ventilation

Fumigation of Rotary mountages

Spray 10% formalin solution on mountages and frames placed on a vinyl sheet. Fold the vinyl sheet to cover the mountages and keep a side for 6 hours.

Disinfection of Rearing House and appliances

Conduct two disinfections with the recommended disinfectants using a power sprayer. An optional disinfection using 0.3% slaked lime solution is also recommended when high incidence of Grasserie or Viral Flacherie were noticed in the previous rearing.

Preparation of chlorine dioxide based disinfectants

Maintenance of hygiene during rearing

- Wash hands in Asthra/Bleaching powder solution before entering the rearing house and also after attending the rearing. Keep Asthra or bleaching powder solution in a shallow tray at the entrance to disinfect the feet.
- Collect diseased/dead/under sized larvae from the rearing bed and burn
- Collect silkworm bed refuse in litter basket/vinyl sheet and dispose by burning or burying
- Store mulberry leaves in a separate disinfected room
- Feed silkworm with quality mulberry leaves
- Rear silkworms under recommended optimum temperature, humidity and spacing so that the larvae grow healthy and resist infection
- Dust slaked lime powder on the rearing bed when the larvae settle for moult
- Dust Ankush/Vijetha and Vijetha Supplement as per schedule

Bed disinfectants	**Schedule**
Ankush	After each moult and 3rd and 5th day of final instar
Vijetha	After each moult and on 4th day of final instar
Vijetha supplement	On 3rd day of 4th instar, 2nd day and 6th day of final instar in addition to vijetha dusting

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AGRIBUSINESS MANAGEMENT IN INDIA: INNOVATION, SUCCESS, AND GLOBAL RESONANCE

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Abstract

Agribusiness in India—where traditional farming meets entrepreneurial dynamism—is evolving into a vibrant ecosystem of production, processing, logistics, and marketing. With rising demand for high-quality produce, value-added products, and sustainable practices, agribusiness management has emerged as a key driver of rural prosperity and economic diversification.

This article explores India's agribusiness landscape, with technical insights, success stories, and innovations, juxtaposing global practices to assess profitability, scalability, and challenges.

India's agribusiness sector represents one of the most dynamic and rapidly evolving components of the global agricultural economy. As the world's second-largest producer of agricultural commodities and home to 58% of the population engaged in agriculture-related activities, India's agribusiness management practices have profound implications for global food security, economic development, and sustainable agricultural practices. This comprehensive analysis examines the current state of agribusiness management in India, exploring innovative approaches, measuring success indicators, and evaluating the sector's growing global resonance while highlighting emerging career opportunities in this transformative field.

Introduction

Agribusiness management in India encompasses the entire spectrum of agricultural value chains, from farm-level production and input supply to processing, marketing, and distribution of agricultural products. The sector contributes approximately 16% to India's Gross Domestic Product (GDP) and provides livelihood support to nearly 600 million people directly or

indirectly involved in agricultural activities (Daily Excelsior, 2022). The emergence of agribusiness as a comprehensive management discipline has revolutionized traditional farming practices, introducing scientific methodologies, technological innovations, and market-oriented approaches that have positioned India as a significant player in the global agricultural landscape.

The evolution of agribusiness management in India reflects a paradigm shift from subsistence farming to commercial agriculture, driven by increasing population demands, urbanization pressures, and the imperative for sustainable resource utilization. This transformation has created unprecedented opportunities for professional management practices, technological integration, and innovative business models that bridge the gap between traditional agricultural knowledge and modern commercial requirements.

Demand, Acceptance, and Market Dynamics

Rising Demand

- Urbanization and changing consumption patterns are fueling demand for packaged, organic, and ready-to-eat agricultural goods.
- Institutional procurement through supermarkets, food tech platforms (e.g., Zomato, Swiggy), and export markets is expanding.

Consumer Acceptance

- Organic and natural farming methods are gaining traction post-COVID.

Local brands leveraging provenance—like ODOPs (One District One Product)—are building cultural loyalty and niche markets.

The Current Landscape of Agribusiness in India

Market Size and Growth Projections

The Indian agribusiness sector is experiencing unprecedented growth momentum. According to recent market analyses, the agritech industry alone is projected to reach $204 billion by 2025, representing a substantial increase from current valuations (AgriBusiness Global, 2023). The broader agritech market is expected to expand from $4 billion in 2022 to $34 billion by 2027, with the food crop segment alone anticipated to grow from $3 billion to $25 billion during this period (IBEF, 2024).

This exponential growth trajectory positions India as one of the fastest-growing agribusiness markets globally, driven by technological adoption, policy support, and increasing investment in agricultural innovation. The sector's expansion is further supported by India's

position among the fifteen leading exporters of agricultural products worldwide, with agricultural and processed food product exports reaching $9,598 million in FY23, representing a 30% increase over the previous year (Zion Market Research, 2024).

Technological Innovation and Digital Transformation

The integration of advanced technologies in Indian agribusiness has catalyzed significant improvements in productivity, efficiency, and sustainability. The Digital Agriculture Mission for 2021-25, initiated by the Indian government, focuses on implementing cutting-edge technologies including Artificial Intelligence (AI), blockchain, remote sensing, Geographic Information Systems (GIS), drones, and robotics (IBEF, 2024).

Prominent technological trends reshaping the agribusiness landscape include Farming-as-a-Service (FaaS), AI-powered crop advisory platforms, drone-based crop surveillance, agribusiness marketplaces, and blockchain-enabled supply chain traceability (Univdatos, 2024). These innovations have demonstrated the potential to increase farmers' incomes by 25-35% while adding $95 billion to the Indian economy through reduced input costs, enhanced productivity, improved price realization, affordable credit access, and alternative income generation (McKinsey, 2023).

Innovation Drivers in Indian Agribusiness Management

Precision Agriculture and Smart Farming

The adoption of precision agriculture techniques has revolutionized farm management practices across India. Smart farming solutions incorporate IoT sensors, satellite imagery, and data analytics to optimize resource utilization, monitor crop health, and predict yield outcomes. These technologies enable farmers to make data-driven decisions regarding irrigation, fertilization, pest management, and harvesting, resulting in improved crop quality and reduced environmental impact.

Machine learning algorithms and predictive analytics are increasingly being deployed to provide contextually relevant and personalized advisory services to farmers. Companies like Jiva are combining AI, machine visioning, and big data analytics to deliver customized recommendations while helping rural entrepreneurs better understand market dynamics and pricing trends (Jiva, 2023).

Supply Chain Innovation and Market Integration

Modern agribusiness management in India emphasizes comprehensive supply chain

optimization and market integration strategies. Digital platforms and marketplace solutions are connecting farmers directly with consumers, processors, and exporters, eliminating intermediaries and improving price realization for producers. Blockchain technology is being implemented to ensure traceability, quality assurance, and transparency throughout the supply chain.

Cold chain infrastructure development and logistics optimization have significantly reduced post-harvest losses while extending the shelf life of perishable products. These innovations have enhanced India's export competitiveness and facilitated access to premium international markets.

Sustainable Agriculture Practices

Environmental sustainability has become a cornerstone of modern agribusiness management in India. Integrated Pest Management (IPM), organic farming techniques, water-efficient irrigation systems, and soil health management practices are being widely adopted to ensure long-term agricultural viability. Biotechnology applications, including the development of drought-resistant and nutrient-enhanced crop varieties, are contributing to sustainable intensification of agriculture.

Carbon farming initiatives and renewable energy integration in agricultural operations are emerging as significant trends, aligning with global climate commitments while creating additional revenue streams for farmers.

Following are some remarkable innovations in agribusiness field:

1. Digital Platforms

Agri-tech startups like DeHaat, Ninjacart, and AgroStar are digitizing procurement, advisory services, and input distribution.

Use of AI-based crop monitoring, IoT, and blockchain for traceability and precision agriculture.

2. Value Addition and Processing

Farmer Producer Organizations (FPOs) and SHGs are setting up mini-processing units for spices, grains, and dairy.

Example: Amul’s model empowers rural women and ensures end-to-end supply chain control.

3. Climate-Resilient Practices

Promotion of millets, aeroponics, zero-budget natural farming (ZBNF) and community-based water harvesting.

Government initiatives like Paramparagat Krishi Vikas Yojana (PKVY) foster sustainable transitions.

Success Stories

Amul (Gujarat)

A benchmark in cooperative dairy agribusiness, Amul transformed Gujarat's rural economy. Today, Amul's multi-tier supply chain and brand value make it globally competitive. Now Amul has entered the Spain's market, soon it will be explore more international markets.

DeHaat (Bihar-based Startup)

Provides end-to-end solutions to small farmers: seed, fertilizer, advisory, and market linkage via app.

Serves 1 million+ farmers across 11 states.

Krishi Star (Maharashtra)

Works with FPOs to create branded products like tomato puree for institutional clients.

Empowers farmers by integrating them into the agri-value chain.

ODOP-Centric Entrepreneurship in Chhattisgarh

Local women-led enterprises producing tamarind-based snacks and tribal forest produce.

Leveraged for export, e-commerce, and tourism.

Global Comparison: India vs. World

Dimension	India	Global Practices (e.g., US, EU, Israel)
Scale of Operation	Mostly smallholder, fragmented land	Consolidated farms with mechanization
Technology Adoption	Emerging via startups, public schemes	Mature adoption of AI, robotics, and satellite imaging
Climate Adaptation	Millet promotion, rain-fed innovations	Smart greenhouses, water recycling systems
Profitability	Improving in dairy, horticulture sectors	High efficiency and export orientation
Policy Support	Mixed—Schemes like PM-KISAN, eNAM	Strong subsidies and insurance cover

India's innovation often lies in community empowerment, frugal solutions, and adaptability—making its agribusiness ecosystem unique, if not yet universally scalable.

Management Strategies and Policy Alignment

- Cluster-based approaches improve logistics and reduce per-unit costs.
- Public-private partnerships (PPP) enhance infrastructure and farmer training.
- Export-oriented strategies through APEDA help globalize Indian agri brands.
- Credit facilitation via NABARD, microfinance, and AgriInfra Funds.

Success Indicators and Performance Metrics

Productivity and Yield Improvements

Indian agribusiness has demonstrated remarkable success in improving agricultural productivity across multiple crop categories. The implementation of scientific farming practices, improved seed varieties, and optimized input management has resulted in consistent yield increases. The integration of technology-driven solutions has enabled farmers to achieve higher productivity per unit area while reducing resource consumption.

Export Performance and Global Market Share

India's agricultural export performance serves as a key indicator of agribusiness success. The country has established itself as a major exporter of rice, wheat, spices, tea, coffee, and processed food products. The consistent growth in export values and market diversification demonstrates the effectiveness of modern agribusiness management practices in meeting international quality standards and consumer preferences.

Financial Inclusion and Farmer Welfare

The success of agribusiness management in India is increasingly measured by its impact on farmer welfare and financial inclusion. Innovative credit delivery mechanisms, crop insurance programs, and direct benefit transfer schemes have improved farmers' access to formal financial services. The development of farmer producer organizations (FPOs) and cooperative structures has enhanced collective bargaining power and market access for smallholder farmers.

Global Resonance and International Impact

Knowledge Transfer and Technology Exchange

India's agribusiness innovations are gaining recognition globally, with several Indian companies and technologies being adopted in other developing countries. The country's experience in leveraging digital technologies for agricultural development has become a

reference point for similar initiatives worldwide. International partnerships and knowledge exchange programs are facilitating the transfer of Indian agricultural technologies and management practices to other regions.

Trade Relationships and Market Expansion

India's agribusiness sector has established strong trade relationships with countries across Asia, Africa, Europe, and the Americas. The country's competitive advantages in specific agricultural commodities have enabled it to capture significant market shares in global trade. Quality certifications, compliance with international standards, and brand development initiatives have enhanced the global acceptance of Indian agricultural products.

Climate-Smart Agriculture Leadership

India's commitment to climate-smart agriculture practices has positioned the country as a leader in sustainable agricultural development. The nation's initiatives in organic farming, natural farming, and regenerative agriculture are being studied and replicated globally. India's participation in international climate forums and agricultural development programs has amplified its influence on global agricultural policies and practices.

Career Opportunities in Agribusiness Management

Diverse Professional Pathways

The agribusiness sector in India offers extensive career opportunities across multiple domains. Graduates can pursue careers in agricultural consulting, farm management, international marketing, seed production, agricultural finance, insurance, and banking (Shiksha, 2025). The interdisciplinary nature of agribusiness creates opportunities for professionals with backgrounds in agriculture, management, technology, finance, and marketing.

Major urban centers including Mumbai, Bangalore, and Gurgaon provide numerous opportunities in agribusiness management, particularly in corporate offices of large agricultural companies (Farmonaut, 2025). Specialized fields such as agricultural finance focus on providing financial services to the agricultural sector, creating demand for professionals with expertise in both agriculture and finance.

Educational Infrastructure and Skill Development

The increasing popularity of agribusiness as a career option has led to the expansion of educational programs and training initiatives. Prestigious institutions offer specialized programs including Master's in Agri-Business Administration and MBA in Agribusiness, designed to

develop comprehensive management skills specific to the agricultural sector (Agricorn, 2024). Career profiles after Agriculture Business Management include agribusiness consultant, agricultural project manager, food processing specialist, agricultural marketing manager, rural development officer, and agricultural technology specialist (ISMR Pune, 2024). The average salary package for MBA agribusiness graduates ranges from INR 3-7 lakhs per annum, with significant growth potential based on experience and specialization (GetMyUni, 2024).

Government and Public Sector Opportunities

The public sector continues to offer substantial career opportunities in agribusiness management through various government departments, research institutions, and development agencies. Agricultural extension services, policy development, and rural development programs require qualified professionals with expertise in agribusiness management principles.

Entrepreneurship and Innovation

The growing agribusiness ecosystem in India provides numerous opportunities for entrepreneurship and innovation. Startups focusing on agricultural technology, food processing, supply chain solutions, and farmer services are attracting significant investment and creating new job categories. The entrepreneurial ecosystem supports both technology-driven ventures and traditional agribusiness enterprises.

Challenges and Future Prospects

Infrastructure Development Needs

Despite significant progress, Indian agribusiness continues to face infrastructure challenges including inadequate cold storage facilities, transportation bottlenecks, and limited processing capacity. Addressing these infrastructure gaps requires substantial investment and coordinated policy support across multiple levels of government.

Climate Change Adaptation

Climate change poses significant challenges to Indian agriculture, requiring adaptive management strategies and resilient agricultural systems. Agribusiness professionals must develop expertise in climate-smart agriculture, water management, and risk mitigation to ensure sustainable agricultural development.

Technology Adoption and Digital Divide

While technological innovation is driving agribusiness growth, ensuring equitable access to digital technologies across diverse farming communities remains a challenge. Bridging the

digital divide requires comprehensive training programs, affordable technology solutions, and supportive policy frameworks.

Conclusion

Agribusiness management in India represents a dynamic and rapidly evolving field that combines traditional agricultural knowledge with modern management practices and technological innovations. The sector's impressive growth trajectory, technological advancement, and global market integration demonstrate its potential to drive sustainable agricultural development while creating substantial career opportunities for professionals.

The increasing recognition of agribusiness as a viable career option reflects the sector's transformation from traditional farming to sophisticated business operations requiring specialized management skills. The integration of digital technologies, sustainable practices, and market-oriented approaches has positioned Indian agribusiness as a significant contributor to global food security and economic development. Future success in Indian agribusiness management will depend on continued innovation, infrastructure development, and human capital formation. The sector's ability to address challenges related to climate change, sustainability, and inclusive growth will determine its long-term impact on both domestic and global agricultural systems. As India continues to strengthen its position as a global agricultural powerhouse, agribusiness management professionals will play crucial roles in driving innovation, ensuring sustainability, and facilitating the sector's continued growth and global resonance.

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DIGITAL PLATFORMS AND ARTIFICIAL INTELLIGENCE: THE NEW FRONTIER OF AGRICULTURAL EXTENSION IN INDIA

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Abstract

India's agricultural extension landscape is entering a transformative phase, moving beyond conventional modes of information dissemination to embrace digital platforms and artificial intelligence (AI) as integral components of farmer outreach. Historically dependent on in-person demonstrations and printed bulletins, extension services are now leveraging mobile applications, SMS advisories, messaging platforms and digital kiosks to deliver hyper-local, real-time information to even the most remote agricultural communities. AI complements this shift by enabling predictive modelling, real-time diagnostics and personalized crop management recommendations based on localized datasets. This convergence of digital tools and intelligent systems is reconfiguring agricultural extension from a linear, one-way communication channel into a predictive, interactive and farmer-centric knowledge ecosystem. Early adoption in states like Maharashtra and Andhra Pradesh demonstrates the potential for a precision extension revolution that can enhance productivity, improve climate resilience and boost farm incomes.

Keywords: Digital Extension, Artificial Intelligence, Precision Agriculture, Farmer Advisory, ICT Tools, Predictive Advisory

Introduction

Agricultural extension in India has long been rooted in traditional methods of knowledge transfer village meetings, field demonstrations, farm visits and direct interactions between extension agents and farmers. While these methods fostered trust and facilitated experiential

learning, they faced inherent limitations: geographical isolation restricted coverage, time lags reduced the timeliness of interventions and resource constraints hindered scalability.

In the past decade, two transformative forces have disrupted this conventional paradigm: the proliferation of digital platforms capable of delivering time-sensitive, location-specific advisories at scale and the integration of AI systems capable of generating such advisories through advanced data analysis. This convergence represents more than a shift in delivery mechanisms; it marks a redefinition of agricultural extension's fundamental purpose. The role of extension is expanding from the mere transmission of scientific recommendations to the collaborative co-creation of solutions, proactive problem anticipation and the empowerment of farmers as informed decision-makers in increasingly complex agricultural environments.

Digital Platforms in Agricultural Extension

Digital platforms have emerged as critical enablers of rapid, wide-reaching agricultural communication. Mobile applications provide dynamic crop calendars, pest alerts and up-to-date market prices. SMS and Interactive Voice Response (IVR) systems cater to farmers without internet-enabled devices, while social media and messaging platforms such as WhatsApp and Facebook facilitate rapid peer-to-peer knowledge exchange. Digital kiosks and call centres serve as information hubs in villages, bridging gaps for farmers without personal access to smart technologies.

These platforms offer distinct advantages. They drastically reduce the time taken to disseminate critical advisories transforming days-long lags into near-instant communication and enable scalability wherein a single extension worker can potentially reach thousands of farmers simultaneously. Furthermore, they provide continuity of service during disruptions such as pandemics, floods, or other disasters that hinder physical outreach. Nevertheless, systemic constraints remain. Internet connectivity in rural India, though improving, is uneven. Language and literacy barriers necessitate translation into local languages and adaptation into voice-based formats. Perhaps most significantly, many farmers exhibit a trust deficit towards purely digital advisories, often seeking validation from human extension agents before implementing new practices.

Artificial Intelligence: Adding the Precision Layer

While digital platforms address the problem of reach, AI addresses the challenge of precision. AI-enabled tools can analyse vast, heterogeneous datasets to produce highly specific

and context-relevant recommendations. In agriculture, this includes the diagnosis of crop diseases through image recognition, predictive modelling of pest outbreaks based on environmental variables, improved weather forecasting through machine learning and market intelligence systems capable of predicting price fluctuations.

Such capabilities represent a qualitative leap from generic advisories to highly personalized, predictive guidance. For instance, AI can recommend specific seed varieties, fertilizer regimens, or irrigation schedules tailored to the micro-conditions of individual fields, thereby aligning agricultural practices with principles of precision farming.

However, several adoption barriers persist. Effective AI systems require access to high-quality, localized datasets for training and calibration. Farmers may be reluctant to rely exclusively on algorithmic recommendations without human mediation, especially when high-value or high-risk decisions are involved. Furthermore, advanced tools like drones and IoT sensors demand infrastructure and financial investments beyond the reach of many smallholders.

Integrating Digital Platforms and AI in Extension Practice

The most impactful models emerging in India combine the scalability of digital platforms with the analytical capacity of AI in hybrid advisory systems. In these systems, AI-generated alerts for instance, regarding a probable pest outbreak are followed by field-level demonstrations and interactions conducted by extension workers. This dual approach not only ensures accuracy and timeliness but also builds trust among farmers. Capacity-building efforts are underway to equip both extension personnel and farmers with the skills to effectively operate and interpret these tools. Local language interfaces are being prioritized to increase accessibility and iterative feedback mechanisms are being integrated to enhance the accuracy and relevance of AI outputs over time.

One illustrative case is Maharashtra's AI-driven pest surveillance initiative for cotton. By combining satellite imagery, pheromone trap readings and farmer-submitted field photographs, the system predicts pink bollworm infestations up to two weeks in advance of visible damage. Farmers receive alerts in Marathi via SMS and WhatsApp after which extension officers conduct practical demonstrations of pest management techniques. This approach has significantly improved adoption rates and demonstrated the value of predictive extension.

Case in Point: Technology in Action

The story of ***Priya Patil***, a turmeric farmer in Jalgaon, Maharashtra, illustrates the

practical benefits of this hybrid model. On noticing unusual leaf spots, she uploaded images to an AI-enabled mobile application, which diagnosed a fungal infection and provided a treatment plan. The recommendation was subsequently validated and operationalized with the guidance of her local agricultural officer. This combination of immediate digital diagnosis and contextual human support enabled Priya to save most of her crop, underscoring the complementary strengths of AI systems and traditional extension methods.

Future Directions

For India to fully realize the potential of this digital AI convergence, several strategic imperatives must be addressed. The rural digital divide must be bridged through investments in broadband infrastructure and affordable smart devices. AI-based advisories must be localized, not only in language but also in cultural and agronomic contexts, with voice-enabled, multilingual interfaces to maximize inclusivity. Building farmer trust will require the continued pairing of AI systems with credible human extension officers. Additionally, the collection of high-quality local agricultural data is essential to improving AI performance.

Equally important is fostering collaboration between public agencies, private agritech enterprises and research institutions to co-develop solutions that are technologically robust yet economically and operationally viable for smallholder farmers.

Discussion and Implications

The rapid integration of digital platforms and artificial intelligence into India's agricultural extension framework must be understood in the broader context of extension science, where multiple paradigms from the classical *transfer of technology* (ToT) model to participatory, farmer-led approaches have competed and evolved over decades. The emerging hybrid digital AI model appears to represent a synthesis between these paradigms: it retains the scalability and scientific rigor of ToT while embedding participatory elements such as feedback loops, localized customization and farmer co-creation of solutions.

Comparatively, several developed and emerging economies have already incorporated aspects of AI-enabled extension. For instance, Australia's "digital agriculture" framework integrates remote sensing data with on-farm IoT devices to provide real-time irrigation scheduling, while Kenya's *Digital Green* initiative uses participatory videos and machine learning to deliver advisory in rural languages. The distinguishing factor in the Indian context is the sheer scale and diversity of its farming population spanning from technologically advanced

horticulture clusters to marginal rainfed farms which demands solutions that are not only sophisticated but also adaptable to varied socio-economic realities.

The use of AI for predictive analytics marks a decisive shift from reactive extension to anticipatory intervention. In theoretical terms, this moves agricultural advisory closer to the *innovation systems* approach, wherein technology is not a static product to be "delivered" but a continuously evolving solution shaped by dynamic interactions among farmers, researchers, extension personnel and market actors. The Maharashtra pink bollworm case illustrates how this model can work effectively: predictive alerts generated by AI were not endpoints but catalysts for collaborative problem-solving, supported by localized demonstrations and farmer engagement.

Nevertheless, the diffusion of such innovations, as per Rogers' *Diffusion of Innovations Theory*, will likely follow an uneven path. Early adopters with higher digital literacy and resource availability may benefit disproportionately, potentially exacerbating the existing gap between progressive and resource-poor farmers. This raises critical policy questions about equity in access to extension services. Furthermore, the sustainability of AI-enabled extension depends heavily on the robustness of underlying data ecosystems. Without continuous, high-quality, localized data on pest incidence, weather patterns, soil health and market trends predictive models risk producing inaccurate or irrelevant recommendations, eroding farmer trust.

There is also a cultural dimension to adoption. Trust in extension advice in India has historically been built through long-term interpersonal relationships. While AI can provide speed and precision, it cannot replicate the social capital embedded in human interactions. Therefore, hybrid models that combine AI-generated advisories with face-to-face validation by trusted extension agents are likely to yield higher adoption rates, as demonstrated in the case of Priya Patil's turmeric farm.

From a governance perspective, the integration of digital platforms and AI necessitates new institutional arrangements. Data privacy, ownership and consent protocols must be established to protect farmers' rights, while interoperability standards should be developed to allow different digital tools to communicate seamlessly. The role of public–private partnerships become pivotal here governments can provide the policy and infrastructure backbone, while agritech startups and research institutions can innovate agile, field-ready solutions.

In terms of long-term implications, the convergence of digital and AI-based extension has the potential to reposition India as a leader in precision agriculture for the Global South. By developing models that are affordable, multilingual and adaptable to resource-constrained contexts, India could export these innovations to other countries facing similar challenges. However, this will require sustained investment not only in technology but also in capacity building, participatory governance and inclusive design.

Ultimately, the effectiveness of digital AI agricultural extension will be measured not merely by the number of farmers reached or the quantity of advisories delivered, but by tangible outcomes in productivity, income stability and climate resilience. For policymakers, this underscores the importance of embedding monitoring and evaluation systems within these digital frameworks, enabling data-driven assessment of impact and iterative improvement of both technology and practice.

Conclusion

The integration of digital platforms and artificial intelligence is reshaping India's agricultural extension into a predictive, interactive and farmer-centric system. This shift represents a fundamental departure from the reactive, one-directional communication models of the past, moving instead toward proactive, personalized and collaborative approaches. If implemented inclusively and supported by the necessary infrastructure, this transformation can become a cornerstone of sustainable, climate-resilient and profitable agriculture in India. By harnessing the synergistic potential of human expertise and intelligent technology, agricultural extension can emerge not merely as a transmitter of information but as a strategic partner in the farmer's decision-making process.

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CONVERTING FARM WASTES INTO VERMICOMPOST-A CASE OF ICAR-NAARM

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Abstract

Vermicomposting is an eco-friendly method of by using organic farm wastes converted into compost, used as fertilizers. The vermicomposting process utilizes various worm species, primarily red wigglers, white worms, and other earthworms. Vermicompost is reached with nutrients organically and it works as a soil conditioner as well healthy for plants to boost the higher yield. Vermicompost is one of the best organic fertilizer to be used in horticultural crops such as flower cultivation, plant propagation, vegetable cultivation to boost the higher yields as well it helps to improve the soil health. In this study the objectives of converting leaf litter and lawn grass clippings into vermi-compost and preparation methods are discussed in detail. The present study is conducted at ICAR-National Academy of Agricultural Research Management, Hyderabad.

Keywords: Advantages, lawn grass, leaf litter, method, vermicompost and waste.

Introduction

Vermicomposting is a method of producing organic fertilizer (vermicompost) by using various kind of farm wastes, leaf litter and many other agricultural waste through the digestive action of various species of earthworms. Vermicompost is the product of the decomposition process using various species of worms, usually red wigglers, white worms, and other earthworms, to create a mixture of decomposing agricultural waste.

The African nightcrawler, scientifically known as Eudrilus euginae, is the compost of manure earthworm that feeds on organic material or farm waste. The other species of earth worms are Redworms viz., Eisenia foetida also known as red wigglers or manure worms, are the best worms to use for vermicomposting. It can stay up to the 6-inch portion of the top soil but is dependent on decaying organic materials above the soil for survival. Vermicompost is a high-quality organic fertilizer consisting of Nitrogen, Phosphorous and Potassium (NPK) and other elements depending on the quality of substrate. The available N in vermicompost is 0.4-1.2 per cent, P is around 0.1-0.3 per cent and K is around 0.15 – 0.6 percentage.

Following steps to be followed for preparation of vermicompost:

- **Selection of suitable site:** Mostly shady, free from water logging, cool temperature, water source and availability of resource material nearby.
- **Beds Preparation:** Readymade HDPE Mobile vermi beds of various sizes are available in the market can be used or permanent cement structure can also be created for making of vermicompost.

Following Size beds are available in the market or even in online mode can also be purchase.

- 6 FT x 4 FT x 2 FT
- 8 FT X 4 FT X 2 FT
- 10 FT X 4 FT X 2 FT
- 12 FT X 4 FT X 2 FT

- **Installation of Bed:** Install the vermi bed by using the wood sticks/Bamboo sticks or any other metal pipes or PVC pipes can also be used for the same. Following is one of the Example used at ICAR-NAARM, Hyderabad for preparation of vermicompost.

HDPE mobile vermicompost beds

Permanent Cement Concrete vermicompost bed

- After preparing the bed, add Soil as first layer than add grass clippings/leaf litter or even chopped dry straw as second layer, it helps to hold moisture & aeration for Earthworms after that sprinkle some water on filled material to maintain moisture. Make sure the moisture level shall not exceed 40-50 per cent. Add fresh cow dung or aged cow dung into the bed as food for earthworms than sprinkle some water on cow dung if it is dry. Continue the process until the Vermibed is full.

  Distribute cow dung to maintain uniform load in the Vermibed. Sprinkle water on top of bed, maintain moisture for Earth worms. Now introduce earth Worms into the Vermi bed, just leave them on the Vermi bed. Cover the bed, ensure no direct sunlight hits the bed. Compost takes 60-75 days for preparation.

Release of earth worms into mobile vermibeds

Methods of Harvesting Worms: Harvesting of worms from vermi beds and vermicompost is done by using three following methods (Bogdanov, 1996).

1. **Manual Method:** It is done by hand sorting or picking the worms directly from the compost beds by hand. Naturally, worms avoid light when the vermicompost containing worms is dumped on a flat surface in a light shade, the worms will quickly go below the surface. Then, harvesting of vermicompost can be started, but, when worms become visible again, it will be stopped. This process is repeated several times until the worms are totally harvested. These worms can be quickly scooped into a container, weighed and prepared for delivery. By selling these worms one can earn good income and the market rate per kg worms is around 300-500.
2. **Self-Harvesting (Migration) Method:** This method is based on the concept that worms migrate to new regions either to find new food or to avoid undesirable conditions such as dryness or light. A box is constructed with a screen bottom. The mesh is usually of size ¼" to 1/8". There are two different approaches. In downward-migration system, worms are forced downward by strong light. The worms go down through the screen into a prepared, pre-weighed container of moist peat moss. Then, the compost in the box is removed and a new batch of worm-rich compost is kept. The process is repeated until the box with the peat moss has reached the desired weight. While, in case of upward-migration system, the box with the mesh bottom is placed directly on the worm bed. It is filled with damp peat moss and chicken mash, coffee grounds or fresh cattle manure. The advantage of this system is that the worm beds are not disturbed. The main disadvantage is that the harvested worms are in material that contains a fair amount of unprocessed food, which can be avoided by removing food and allowing the worms to consume what is left before packaging. This system is used extensively in Cuba with the difference that large onion bags are used instead of boxes (Cracas, 2000).
3. **Mechanical Method:** Mechanical harvesting is the quickest and easiest method for separating worms from vermicompost. Mechanical harvester with a rotating cylinder are composed of screen material of different mesh sizes. The cylinder is rotated by a small electric motor mounted on one end of the cylinder. As the cylinder rotates, the castings fall through the screen. The worms 'ride' the entire distance of the tromme land pass through the lower end into a wheel barrow.

Methods of Harvesting Vermicompost: Following three methods are in use for harvesting vermicompost

1. **Cone Method:** The contents of the vermi beds/bins can be placed in the shape of cones on a taurpalin or plastic sheet and later the worms are allowed to burrow down. The harvested compost will be transferred to a separate storage container and the worms are transferred to new vermi beds.
2. **Migrating Method:** This is a handy method of harvesting the vermicompost quickly. The compost which is ready should be pushed to one side. Simultaneously, prepare new bedding on another side of the vermi bin/bed and place the waste. Now, addition of food material has to be stopped for one side and added on another side. Likewise, harvesting sides can be alternated on a continual basis.
3. **Scoop Method:** This is a perfect method for people who only need a small amount of compost at a time. Worms are allowed to burrow away by gentle exposure to the light by opening the vermi bins/beds. This can also be done by stirring the surface. Then, after about 10 minutes, top layer of castings can be scooped off. Worms in the compost if any, have to be removed. This process can be repeated.

Economics of Vermicomposting: The cost of production by vermiculture is significantly low by more than 60-70 per cent and is simply insignificant as compared to chemical fertilizers. The food produced will be a safe, chemical-free for the society. It is a win-win situation for both producers (farmers) and the consumers (feeders). As vermicompost also helps the crops to attain maturity and reproduce faster, it shortens the 'harvesting time' (Sinha et al., 2007), this further cuts on the cost of production and also adds to the economy of farmers as they can grow more crops every year in the same farm plot. People are earning from Rs. 5 to 6 lakhs every year from sale of both worms and their vermicompost to the farmers.

Advantages of Vermicomposting

- It helps to develop roots of the plants
- It helps to improve the physical properties of the soil
- It helps to soil to hold water and maintains moisture
- It helps to improve the soil fertility
- It helps to improve plant health and good yield
- It enhances the soil's biological properties
- It helps to improve the soil porosity

- It helps soil to retain nutrients

Conclusions

The increasing interest of people in organic farming across the globe, vermicompost is one of the best potential organic source to nourish the plants in various fields of Agriculture, Horticulture, Floriculture and various kind of plant propagations. Vermicompost is rich in various macro-nutrients, plant growth promoting hormones, beneficial soil microbes and mycorrhizal fungi. Keeping this in mind and increasing demand of organic foods globally and its pivotal role in maintaining the soil health and productivity, vermicompost is definitely going to be a viable component of organic farming. The use of vermicompost will bring economic prosperity to the farmers and the nations with 'environmental security' for the earth.

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Vermicomposting – Definition, Types, Objectives, Process, Etc.

Vermicomposting is a natural method for producing compost using earthworms. Vermicomposting is also called composting with worms. Vermicomposting is considered an eco-friendly method of utilizing organic wastes into compost that can be used as fertilizers. The vermicomposting process utilizes various worm species, primarily red wigglers, white worms, and other earthworms. Vermicomposting leads to the production of a mixture of bedding materials, decomposing food or vegetable waste, and vermicast. Vermicompost is a nutrient-rich organic fertilizer and soil conditioner that is relatively simple for plants since it contains water-soluble elements. Inorganic fertilizer made from worm castings is occasionally utilized. In this article, we will discuss the objectives, types, methods, advantages, and disadvantages of vermicomposting.

What is Vermicomposting?

A scientific process by which earthworms and microorganisms are used to help stabilize active organic waste and transform it into a useful soil supplement and source of plant nutrition is called **Vermicomposting**. It is one of the simplest methods for turning agricultural waste into high-quality compost. Earthworms consume biomass and release the digested remnants as worm castings. Worm casts are frequently called "Black gold." The castings are rich in nutrients, contain compounds that encourage growth and have favourable soil microflora, all of which can limit dangerous germs. Because vermicomposting treats organic wastes more quickly than traditional composting, it has become more popular in both industrial and household utilization of organic wastes.

Types of Vermicomposting

The amount of production and the structures used for composting determine the different types of vermicomposting.

- **Small-Scale Vermicomposting**: A farmer can collect 5 to 10 tones of vermicompost per year when vermicomposting is on a small scale to suit personal needs.
- **Large-scale vermicomposting**: It is carried out on a commercial scale, producing between 50 and 100 tonnes of organic waste per year.

Methods of Vermicomposting

There are many ways to create vermicompost, but the Bed and Pit procedures are the most popular.

- **Bed Method**: By constructing a bed of organic material measuring $6 \times 2 \times 2$ feet, composting is done on the pucca or kachcha floor. This approach is simple to maintain and use.
- **Pit Method**: Composting in pits that are $5 \times 5 \times 3$ feet in size and made of cement is the pit method. Thatch grass or any other native materials are used to cover the structure. This method is not favoured since it produces more waste, has poor aeration, and costs more to produce.

Objectives of Vermicomposting

The major objectives of vermicomposting are:

- To compost organic wastes to feed nutrient-deficient soil with high-quality manure as well as to dispose of solid organic wastes.

- A large amount of organic waste produced by agricultural operations, dairy farms, and animal shelters that is typically discarded as waste and emits an unpleasant odour can be used by correctly composting it to create an end product with added value.

Vermicomposting Materials

Animal waste, kitchen garbage, farm waste, and forest litter are all examples of decomposable organic waste that are frequently utilized as composting ingredients. The main raw sources are typically dried chopped crop wastes and animal manure, primarily cow dung. A mixture of both leguminous and non-leguminous crop leftovers improves the vermicompost's quality. There are several species of earthworms, including *Perionyx excavatus* (blue earthworm), *Eisenia foetida* (red earthworm), and *Eudrilus eugenia* (night crawler). Because of its rapid reproduction rate and ability to turn organic matter into vermicompost in about 45 days, red earthworms are recommended. Since it is a surface feeder, vermicompost is created by the top conversion of organic resources.

Process of Vermicomposting

The following describes the full vermicomposting procedure:

Preparation of Vermi Bed

The process of preparation of vermi bed involves the following steps;

- A thin (5 cm) layer of shattered bricks and coarse sand is laid on top of a layer of moist, loamy soil called the vermi bed, which is roughly 15 to 20 cm thick.
- The loamy soil is added with earthworms, which will make it their home there.
- A compost pit measuring around 2 meters by 1 meter preferably by 0.75 meters with a vermi bed layer between 15 and 20 cm thick can accommodate 150 earthworms.
- After that, a few random lumps of fresh cow manure are scattered over the vermi bed.
- After that, dry leaves or, preferably, chopped hay, straw, or agricultural waste biomass are stacked into the compost pit to a depth of about 5 cm.
- The pit is kept wet for the following 30 days by watering it as required.
- The bed should neither be dry nor wet.
- The pit can then be covered with a jute bag to keep the birds away.
- Plastic sheets should not be used on the bed, since they trap heat.

- After the first 30 days, it is covered with moist, pre-digested organic waste of animal and/or plant origin from the kitchen, hotel, hostel, or farm, with a thickness of around 5 cm. Do this twice per week.
- To maintain the pits moist, regular watering should be done.
- If the weather is very dry, it should be examined regularly.
- All organic wastes should be turned over or mixed frequently.

Preparation of Compost Pit

The following steps should be taken for the preparation of the compost pit;

- A compost pit of any practical size can be built in a field, garden, or backyard.
- It could be a single pit, two pits, or a tank made of brick and mortar with the appropriate water outlets in any size (a reasonable size is 2 m by 1 m by 0.75 m).
- To counteract the ant problem, place a water column in the middle of the vermipits' parapet wall.
- The "four chambers" pit will make it simple for earthworms to go continuously from one chamber that has fully composted material to the chamber that contains the pre-processed trash.

Nutrient Content of Vermicompost

The origin of the raw material and the type of earthworm used determine the amount of nutrients in compost. Beyond other nutrients, a fine worm cast is a rich source of N, P, and K. Vermicompost contains nutrients that are immediately available and released one month after application.

Parmeters	Content
pH	6.8
Organic Carbon %	11.88
Organic Matter %	20.46
C: N ratio	25-30
Total Nitrogen (%)	1.02
Available Nitrogen (%)	0.50
Available Phosphorous (%)	0.30
Available Potassium (%)	0.24

Ca (%)	0.17
Mg (%)	0.06

Advantages of Vermicomposting

The principal advantages of vermicomposting are:

1. Aids in plant development, germination, and crop yield.
2. Enhances the soil's physical structure.
3. By using vermicompost, the soil becomes more fertile and water-resistant.
4. Develops the plant's roots.
5. Provides auxins, gibberellic acid, and other plant growth hormones to the soil as fertilizer.
6. Adds essential nutrients to the soil like nitrogen, phosphorus, and potassium.
7. Helps recycle organic waste in a useful manner.
8. Can be done indoors and in small structures allowing year-round availability of compost.

Disadvantages of Vermicomposting

The following are some major disadvantages of vermicomposting:

1. The process of transforming organic waste into useful forms is time-consuming and can take up to six months.
2. Vermicomposting requires a lot of maintenance. The feed must be added regularly, and it is important to watch that the worms are not overfed.
3. They promote the development of diseases and pests like fruit flies, centipedes, and flies.
4. It emits an extremely unpleasant smell.
5. The container for waste shouldn't be either dry or very damp. Periodically, the moisture levels must be checked.
6. Limitation on the amount of waste that can be composted at a time.
7. Hot and cold weather can affect the activity of the worms impacting the rate of composting.

Application of Vermicomposting

Following are some of the most common applications of vermicomposting;

1. The worm castings can be used as an alternative for fish feed.

2. Extracts and fluids from earthworms can be used in therapeutic products.
3. Improvement of the soil quality degraded by chemical fertilizers and pesticides.
4. Used in agricultural studies.
5. Worm cultivation can be used for commercial purposes also.
6. Can be used widely in horticulture settings.

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CROP MODELING: A NOVEL APPROACH TO SUSTAINABLE PRODUCTION IN HORTICULTURE

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Abstract

Crop models have long been powerful tools in figuring out the physiological mechanisms that determine crop yield in relation to the environment. They are used to estimate seasonal changes in quality traits like size, dry matter, water content, and the concentration of sugars and acids, which are very important for flavour and aroma in horticultural crops. The production process of horticulture can be described as an open and highly complex system affected by weather, soil, insects, diseases, weeds, nutrition, prices, and interactions of these many factors. There are various types of models available, with varying parameters and precision.

Introduction

The complex agribusiness of farming includes a range of activities, including the production of cereals, fruits, vegetables, livestock, and poultry. Climate, ecological environment, resource availability, and knowledge of crop-specific agro-techniques are some of the factors that affect crop agronomic practices. Therefore, understanding how each factor affects crop growth and yield is essential. This is made possible by crop models, which let us make the adjustments we need to enhance the management of our farm as a whole.

WHAT IS MEAN BY A CROP MODEL?

It is a condensed explanation of a system, frequently in the form of a mathematical model, that aids in computations and forecasts. In this sense, a model is a computer program that, given the right input data, may be executed multiple times to calculate a number of mathematical or statistical expressions (equations) that control the relationships between crop development and

the environment.

WHY CROP MODELING?

1. To put into practice the knowledge we have gained from field experiments.
2. To offer a structure that promotes cooperation across disciplines.
3. To promote the application of systems analysis to problem-solving.
4. To offer dynamic, quantitative techniques for cropping system analysis.

INPUT DATA REQUIREMENT:

A. Weather information: Including maximum and minimum temperatures, precipitation, relative humidity, sun radiation, and wind speed.

B. Crop information: Yield, LAI, phenology (days to anthesis, days to maturity, etc.), crop type, and variety.

C. Soil information: Physical (texture, structure) and chemical characteristics (pH, EC, micro and macronutrient status, soil organic carbon, moisture, saturation, field capacity, and soil wilting point).

D. Information on crop management: Planting date, seed rate, and planting depth; quantity, kind, and timing of inputs in the agricultural field (fertilizer, irrigation, manure).

E. Pest information: Pest type and name, attack method, and population at various phases of crop growth. Only models with the pest module include information on insects or other pests.

TYPES OF CROP MODELS:

Depending upon the purpose for which it is designed the models are classified into different groups or types. A few of them are as follows.

1. **EMPIRICAL MODELS:** Empirical models are used to estimate the final yield. They are straightforward explanations of observed data that are typically expressed as regression equations (with one or a few components). The main steps in this method are looking at the data, choosing an equation or set of equations, and fitting them to the data. The mechanisms underlying the response are not explained by these hypotheses. The relationship between leaf area and leaf size in a particular plant species, the response of crop yield to fertilizer application, and the relationship between final yield and stalk height alone or in combination with stalk number and/or diameter are a few examples of these models.
2. **MECHANISTIC MODELS:** A mechanistic model is one that uses lower-level features to explain how the system behaves. Thus, at the lower levels, there is a mechanism, comprehension, or explanation (e.g. Cell division). These models can explain how and why a specific response happens, as well as replicate pertinent physical, chemical, or biological processes. In order to explain agricultural yield, the modeler often begins with some empirical data and adds more parameters and variables as information is acquired. As a result, the system is divided into separate parts and given designated procedures.
3. **STATIC AND DYNAMIC MODELS**: Even if cropping systems' final results accrue over time, a static model does not include time as a variable. On the other hand, most dynamic models are first stated as differential equations and explicitly include time as a variable.
4. **DETERMINISTIC MODELS:** A deterministic model is one that, in the absence of any related variance, random element, or probability distribution, gives precise predictions for quantities (such as rainfall or crop production). However, biological and agricultural systems

are inherently subject to variances brought on by errors in recorded data and heterogeneity in the material being dealt with. Despite these inherent variances, deterministic models may be sufficient in some situations but may not be in others, such as rainfall prediction. Deterministic models are less effective the more uncertainty there are in the system.

5. **STOCHASTIC MODELS:** It is wise to create a stochastic model that provides both the expected mean value and the corresponding variance when variation and uncertainty are large. Stochastic models, however, can easily become complicated and are often technically challenging to manage. Therefore, it is best to try a deterministic method to the problem at first, and then a stochastic approach only if the results are insufficient and unsatisfactory.
6. **SIMULATION MODELS:** These comprise a collection of models created to replicate a system's behaviour. They incorporate the variability associated with daily changes in weather and soil conditions since they are made to replicate the system at short time intervals (daily time-step). A significant amount of input data (climate parameters, soil properties, and crop parameters) must be supplied for the model to operate due to the brief simulation time-step. These models can be used to explore a variety of management strategies at a cheap cost and typically provide the ability to specify management alternatives.
7. **OPTIMIZING MODELS:** Optimising models are designed to identify the optimal choice for management inputs to enable the system to function practically. Decision rules that are compatible with some optimization algorithms are used to derive solutions. This results in limitations in their ability to depict the stochastic and dynamic elements of agricultural systems since it imposes some rigidity on their structure.

HOW CROP MODELS WORKS?

1. Based on soil characteristics, climate, and crop species, crop models calculate the daily biomass increase in individual plant organs (stems, leaves, roots, grains/tubers, etc.) as well as the development of plants from seeding to maturity.
2. To replicate crop growth over the course of the growing season, crop models also take soil dynamics such as the availability of water and nutrients into consideration.
3. FARM/IT also uses soil moisture content and rainfall to estimate nitrogen mineralization, leaching, and volatilization.

STEPS IN MODELING:

Define goal

↓

Define system and its boundaries

↓

Define key variables in system

↓

Preparation of flowchart

↓

Evaluation

↓

Calibration

↓

Validation

↓

Sensitivity analysis

Fig. 1: Flow chart of steps in modeling

APPLICATIONS OF CROP MODELS IN HORTICULTURE

1. Crop models are necessary for management options, policy analysis, and yield forecasts.
2. Easy marketing based on yield forecasts (when various produce would arrive at the market).
3. Yield gap estimation: key elements and their effects.
4. We can increase our profit margins by adjusting our harvesting to take advantage of the lean phase during the marketing season.
5. Fruit production can also be planned to coincide with regional fairs and festivals.
6. We need to model the "architecture of fruit trees and linkages between pruning and flower and fruit growth" in order to maintain the health of fruit trees. For instance, in the biomechanical modeling discipline.
7. The model's biological component consists of the physiological production processes from seeding to harvest, whereas its economic content consists of production costs and profits.
8. The biophysical model can determine the yearly fruit production by using features like tree density and pruning/training schedules.

9. The effects of climate fluctuation and change on human welfare.
10. Percolation of environmental effects, greenhouse gas emissions, nitrogen losses, and precision farming.

LIMITATIONS OF MODELING

1. These apps need a lot of data, some of which may not be visible to the user.
2. It is crucial to have a basic understanding of computers and computer language.
3. Only a few people have a hazy understanding of and acceptance of modeling.
4. Models created for one location cannot be used in the same way as models created for other regions.
5. Models cannot provide findings that are 100% correct, even when a large number of variables are taken into consideration.

Conclusion

Crop modeling has emerged as a key horticultural research tool throughout the past two decades. Model creation and implementation as a research tool can help us find knowledge gaps, allowing for more focused and effective study planning. This new generation is actually essential to keep up with the progress in fruit genetics in terms of fruit quality. Model portability would be increased and the danger of error or misuse would be reduced by the use of software quality assurance techniques, the adoption of standard units, the creation of inputs and outputs, the selection of variables, the creation of appropriate documentation, and constraints. Research may be conducted efficiently using a model that has been carefully calibrated and assessed. This will ultimately save time and money and greatly aid in the development of sustainable agriculture that will meet the world's food needs.

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NUTRIENT DEFICIENCY IN PULSES

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Introduction

Pulses also known as leguminous crops, are one of the oldest and most widely consumed food groups around the world. They belong to the family **Fabaceae** and include crops such as lentils, chickpeas, pigeon peas, beans, and mung beans. Pulses plays a major role in human diets for vegetarians and they had the ability to fix nitrogen in the soil. A **nutrient deficiency in plants** is a physiological disorder that arises when a plant doesn't receive enough of one or more **essential nutrients** because the nutrient is lacking in the soil or the plant can't access it due to soil conditions or pH issues.

Nutrient Deficiencies in Pulses

1.Nitrogen (N) Deficiency

Symptoms: Yellowing of older leaves, stunted growth, poor nodulation.

Causes: Poor soil nitrogen, ineffective Rhizobium inoculation.

Management:

- ✓ Use nitrogen-fixing biofertilizers (e.g., Rhizobium species).
- ✓ To ensures proper seed inoculation.
- ✓ Apply nitrogen fertilizer as basal dose.

2. Phosphorus (P) deficiency:

Symptoms: Stunted growth, dark green or purplish leaves, delayed flowering.

Causes: Low soil phosphorus availability in acidic soils

Management:

- ✓ Apply phosphate fertilizers (e.g., single super phosphate).
- ✓ Use phosphorus-solubilizing bacteria (PSB).
- ✓ Maintain soil pH for optimal P availability

3. Potassium (K) Deficiency:

Symptoms: Leaf margin browning, weak stems, increased susceptibility to pests.

Causes: Sandy or highly leached soils.

Management:

- ✓ Apply muriate of potash (KCl)
- ✓ Use organic amendments like compost and wood ash.

4. Sulphur (S) Deficiency

Symptoms: Yellowing of young leaves, poor pod formation.

Causes: Low organic matter in soil, continuous use of high-analysis fertilizers with little S.

Management:

- ✓ Apply gypsum or elemental sulphur.
- ✓ Use sulphur-containing fertilizers (e.g., ammonium sulphate).

5. Zinc (Zn) Deficiency

Symptoms: Interveinal chlorosis in young leaves, stunted growth.

Causes: High pH soils (alkaline),continuous cropping.

Management:

- ✓ Foliar spray of zinc sulphate (0.5%).

- ✓ Soil application of zinc sulphate (25–50 kg/ha).

6. Iron (Fe) Deficiency

Symptoms: Interveinal chlorosis of young leaves, especially in calcareous soils.

Management:

- ✓ Foliar spray of ferrous sulphate.
- ✓ Improve organic matter to enhance iron availability.

Causes of Nutrient Deficiency in Pulses

- ✓ Soil Type and pH: Alkaline or sandy soils lacks micronutrients.
- ✓ Continuous Monocropping: Leads to depletion of specific nutrients.
- ✓ Poor Soil Management: Inadequate fertilizer application or lack of organic inputs.
- ✓ Waterlogging or Drought: reduces nutrient uptake by roots.
- ✓ Lack of Crop Rotation: Reduces microbial population and nutrient cycling.

Consequences of Nutrient Deficiency

- ✓ Reduced flowering and poor pod formation
- ✓ Lower protein content and seed viability.
- ✓ Nutrient deficient plants leads to pests and diseases.
- ✓ Reduced productivity leads to lower income.

Nutrient Management Strategies

- ✓ Regular soil tests are taken to aid fertilizer application.
- ✓ Combining organic, inorganic, and biological sources should be given .
- ✓ Seed Treatment to prevent pest and diseases.
- ✓ Foliar application of micronutrients during vegetative and flowering stages.
- ✓ Application of fertilizers based on crop requirements

Conclusion

Nutrient deficiencies in pulses are major problem in achieving optimal productivity. Soil testing, balanced fertilization, bio fertilizers, and proper crop rotation can help to overcome these nutrient deficiencies. Ensuring nutrient adequacy not only improves crop health and yield but also supports the nutritional security of populations dependent on pulses as a major protein source

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CRUCIAL ROLE OF DRAINAGE IN PADDY FIELDS

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Abstract

Efficient drainage is often overlooked in paddy cultivation, where water management is typically associated with irrigation. However, proper drainage is equally vital to ensure optimal plant health, yield, and soil sustainability. In paddy fields, excess water whether from heavy rainfall, poor soil permeability, or over-irrigation can lead to waterlogging, root suffocation, and increased pest and disease incidence. This article explores the critical role of drainage in maintaining the ideal moisture balance, preventing nutrient leaching, and promoting healthy root aeration in rice crops. Drawing on field level experiences and agronomic research, the article highlights the importance of designing and maintaining appropriate surface and sub-surface drainage systems tailored to different soil types and rainfall patterns.

Keywords: Paddy cultivation, drainage management, waterlogging, surface drainage, sub-surface drainage, agronomic practices, wetland rice.

Introduction

Increasing population demands increased food production. Among the food grains, rice is a major contributing grain to the food bowl and it is also the staple food for the majority of South Indians. With the changing scenario in the agriculture, after the introduction of WTO and globalization, it has now become more of quality and export-oriented agriculture than meeting our food requirements. Though increasing the yields of the crops is one of the important aspects of our agricultural research, the marketing of the produce mainly depends upon the quality of the grain produced.

This can be achieved not only by selecting the suitable variety, which proved to be most preferred by the consumers, but also growing the crop in an appropriate season with favourable climatic conditions for the crop growth and in an unfavourable condition for the pest and disease occurrence, as well as, in a healthy and fertile soil environment. Provision of drainage is one such prerequisite to help the crop to grow in a healthy soil environment, which means, the essential nutrient elements are at optimum supply to meet the crop requirement, as well as, free from toxic elements / gases which may get accumulated under impeded drainage conditions. This article deals with such aspects related to the soil drainage, reasons for poor drainage and its impact on paddy crop with suitable amelioration.

Causes and effect of poor drainage in a paddy field

Rice is the only crop that can grow under submerged conditions, since it has the ability to translocate oxygen through its system to its rhizosphere. The cultivation of rice involves puddling of the field with excess water to make the water to stagnate. Puddling generally refers to breaking down soil aggregates into ultimate soil particles.

Though puddling is done to favour paddy growth, it creates a lot of physical, physico-chemical and chemical changes, which are leading to poor drainage conditions. The changes that result due to puddling are:

- Destruction of soil aggregates
- Elimination of non-capillary porosity
- Reduction on total porosity
- Increased moisture retention
- Decreased evaporation
- Decreased percolation losses
- Reduction in bulk density
- Decreased redox potential
- Conversion of ferric and manganic ions in to ferrous and manganous ions resulting in the toxicity of theses ions in the soil environment
- Accumulation of toxic gases like hydrogen sulphide and methane in the rhizospere
- Accumulation of ammonia
- Increased denitrification and volatilization losses
- Decreased nitrification rate

- Increased level of P availability
- Decreased zinc, copper and molybdenum availability

Some of the above said effects are favourable for paddy crop and some are harmful to the growing rice crop. Hence to optimize the effects of puddling, it is always advisable to manage the water level in the field by alternate wetting and drying so that the oxidized and reduced conditions co-exist resulting in a better crop growth. This can be achieved by mere water management techniques, but in places where water cannot be managed as per the requirements due to the location of the field, provision of drainage is the only alternative.

Symptoms of impeded drainage conditions

The impeded drainage condition can be diagnosed by careful investigation of the soil profile. However, under field conditions, when the crop is in the field, it is not necessary to dig the soil profile and identify the impeded conditions. The following criteria may be considered for identifying the poor drainage condition.

Though the paddy crop loves to grow under submergence, continuous inundation of water results in the certain physiological disorders depending on the causes for the poor drainage conditions. For instance,

- A normal soil may also develop symptoms of impeded drainage due to continuous inundation resulting in the toxicity of ions like Fe and Mn which shows toxicity symptom in the plant itself.
- Under conditions of excess sulphur either in the soil in the organic form or from the irrigation water, continuous submergence result in the reduction of sulphur in to hydrogen sulphide causing root suffocation and death root cells. This can be identified by the rotten egg smell evolved from the soil surface as well from the dark coloured gleyey surface horizon.
- Under sodic soil conditions the soil will be slushy and soft when moist and very hard when dry. It also takes longer time for drying up. Such a situation needs application of gypsum (based on the gypsum requirement) and subsequent draining of excess sodium.

DRAINAGE

Drainage is the provision of suitable system for the removal of excess water either by rainfall or by irrigation from the land surface so as to facilitate favourable soil moisture condition for the growth of plants to give sustained yields over longer periods of time to prevent

accumulation of salts in the case of garden land crops and to prevent accumulation / toxicity of elements and gases in the case of submerged soils. In India, there are 5 million hectares of lands affected by poor drainage, out of which 1.5 million are affected by salinity and water logging, another 1.5 million hectares affected by salinity and alkalinity with low sub soil water table and remaining area subjected to rise in water table to within 3-10 feet from the surface.

The poor drainage was evidenced by the presence of mottling in the soil profile even during the dry summer seasons. It was thus concluded that the low yields of paddy crop in the water logged soil can be directly linked to the poor drainage conditions and any improvement in the drainage will definitely improve the yield potentials of the soils.

Benefits of Drainage

As mentioned earlier, the poor drainage conditions actually created by puddling can have beneficial and harmful effects in the growing paddy crop. The benefits due to provision of drainage are definitely greater than the derived benefits that are created in the soil due to puddling. Hence, the drainage should be provided to facilitate the following advantages:

- Removal of excess water resulting in the improved aeration in the root zone
- Vigorous root growth resulting in increased yield
- Oxidation of harmful substances and thereby promoting and optimizing the nutrient availability

Classification of drainage

Though the benefits of drainage are proved beyond doubt by research, the ultimate adoption depends on the economic aspects of the method of drainage suggested for the given condition. It is to be understood that unlike the application of fertilizers, which increases the yield, the provision of drainage though not increases the yield, prevents the damages caused, there by resulting higher returns. However, evidences are there that improved drainage conditions can definitely enhance the grain yields. This can be confirmed by the fact that over years bumper yields were achieved during the drought years than during the surplus years with respect to water availability in Cauvery. Hence provision of drainage is essential not only to enhance the yield but also to improve the quality of the harvested produce.

The drainage is classified in to two major systems viz., (i) Surface drainage system and (ii) sub surface drainage system.

Surface drainage system

The system of providing large out let channel or field ditches for the removal of excess surface water resulting from excess rainfall, excess irrigation and/or inability to drain in the natural stream, from seepage from water sources, from over lying areas etc. is known as surface drainage. It is in fact is done in the paddy nursery to facilitate the germination of the sown seeds by connecting the depressions in such a way water do not accumulate in the field. It is done in a very minor way but in the transplanted crop, this can be done systematically by providing lateral, cross and main drainage channel arranged as per their elevation and the excess water taken away from the field to the natural stream. However, utmost care needs to be taken while draining the field after fertilizer application which may result in the leaching of costly fertilizer nutrient elements in the drainage water. This can be prevented by applying the fertilizer with a thin film of water and allowing the nutrient element to get fixed and / or complexed with soil colloids. There are lots of advantages of choosing the surface drainage system with some disadvantages also. They are:

The Advantages are,

- The initial cost is very less compared to sub surface drainage
- The surface drainage system is always visible for inspection and hence defects can be easily rectified
- Removal of excess water from fields having soils of poor permeability which cannot be effectively drained by tile drainage can be drained by surface drainage

However, the disadvantages of surface drainage are,

- It occupies valuable crop lands
- Open ditches cause hindrance to the moving implements drawn by bullocks and tractors
- They are subjected to silting and growth of weeds which are to be cleared periodically
- Since they are open and wet, they are susceptible to damage by animals and rodents

Depending on the topography of the land, soil characteristics, crops intended to be grown and the existing outlet facilities based on the economical planning and design the type of surface drainage can be (i) random field ditches (ii) land smoothing (iii) bedding (iv) parallel field ditches (v) parallel lateral open ditch system and cross slope ditch system.

Sub surface drainage system

In this system, the removal of excess water which occurred either through shallow ground

water table, excess irrigation and / or rainfall, seepage from the neighboring fields and from the overlying lands is effected by providing underground outlets at a convenient depth to drain off free sub soil water and to convey it to natural outlets so as to lower the water sufficiently.

As in the case of surface drainage system, the sub surface drainage system also has some advantages and disadvantages.

The advantages are,

- They don't occupy the valuable crop land
- They are least interfering with farm operations
- Require less maintenance
- Drain the sub soil and aids extensive root system
- Not damaged by animals

The disadvantages are,

- The initial investment is more
- They are ineffective in soils having very low permeability
- Inlet and outlet should be maintained properly
- Any failure in the system cannot be diagnosed easily

Conclusion

To conclude, drainage is absolutely essential not only for upland crops but also to a crop like paddy, which prefers to grow under, submerged condition. This means that the paddy crop has to grow alternatively in a wetting and drying soil moisture regime, so that both the advantages and disadvantages of puddling can be optimized to the maximum extent. Especially in areas with excess organic and / or inorganic sulphur in the soil which may release hydrogen sulphide on continuous submergence may prove highly toxic and result in the complete failure of the crop and hence proper water management is absolutely essential to prevent such damages.

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ELECTRONIC - NATIONAL AGRICULTURAL MARKET (E-NAM)

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Abstract

To modernize agricultural trade and improve price realization for farmers, the Government of India launched the e-NAM (electronic National Agricultural Market) initiative by March 31, 2018. The system had integrated 585 Agricultural Produce Market Committees (APMCs) across 16 states and 2 Union Territories through a unified digital platform. Over 1.64 crore farmers and approximately 1.91 lakh traders and commission agents have joined the platform. The e-NAM currently covers only around 11% of the country's wholesale markets. A notable advantage of the platform is that it supports intra- and inters state trade, facilitating broader market access and better pricing. Initial research indicates mixed effects on market arrivals and farmer earnings with variation observed across different regions of India.

Introduction

Agricultural marketing in India has progressed from locally confined trade systems to a vision of nationwide connectivity, aiming to reduce the gap between producers and end consumers. With the emergence of new mechanisms such as digital platforms, model APMC laws, warehousing systems, pledge financing and contract farming. Indian agriculture is gradually embracing reform-oriented strategies. Realizing these changes will require infrastructure investment, technological adoption, and farmer education.

According to a NABARD survey, nearly half (48%) of Indian households engage in farming with crop cultivation alone contributing an average of Rs. 3140 per month to household

income. While India ranks among the world's top producers of key agricultural commodities such as pulses, milk, fruits, vegetables and cereals poverty remains a challenge especially in rural regions where agriculture is the main livelihood source.

The e-NAM Initiative

Initiated in 2016, e-NAM is a digital marketplace aimed at integrating selected APMCs across the country to create a common, unified trading space. This electronic portal helps farmer's access buyers from various parts of India through online bidding, reducing the role of middlemen and multiple market charges.

Key stakeholders involved in implementing e-NAM include:

- Central Government: Offers policy support and standardization
- Small Farmers Agribusiness Consortium (SFAC): Lead implementing agency
- Nagarjuna Fertilizers and Chemicals Ltd.: Maintains the online platform
- Directorate of Marketing and Inspection (DMI): Assists with quality and standardization
- National Informatics Centre (NIC): Provides IT infrastructure
- State Governments & APMCs: Handle warehousing, trading logistics and local dispute resolution

Technology and Agricultural Marketing

A strong agricultural marketing system supports efficient price discovery, better supply chain management and greater participation in value-added markets. e-NAM exemplifies how technology can transform traditional agricultural systems, offering farmers access to broader markets and more competitive pricing.

Technology adoption typically progresses in phases initially slow, then rapidly expanding, and finally stabilizing. Successful adoption depends on:

1. Motivation for change
2. Suitability of the technology within the current system
3. Perceived value and visible benefits

As e-NAM becomes more widely adopted, it is expected to redefine traditional buyer-seller relationships and bring about a significant shift in the social dynamics of agricultural trade.

Objectives of e-NAM

- Link APMC markets nationwide via a digital trading platform
- Harmonize marketing rules and procedures across states

- Enhance farmers' access to diverse buyers and markets
- Introduce quality testing to support transparent bidding
- Help stabilize prices and ensure better produce for consumers

Advantages of e-NAM

For Farmers:

- Fair and transparent trade practices
- Improved price discovery
- Greater access to multiple markets
- Real-time mandi price updates
- Faster payments
- Potential to build a strong financial track record
- Wider reach and better selling prospects

For Traders:

- Expanded access to multiple APMCs
- Participation in a single, connected national platform
- Timely information on produce arrivals and trades
- Access to commodity quality details
- Convenience through mobile applications
- Integrated digital banking and payment options

For Mandis:

- Digital automation of transactions
- Centralized data on trade volumes and arrivals
- Real-time reporting and analysis tools
- Improved tracking of pricing trends
- Streamlined financial record-keeping

Global Comparisons

Several countries have adopted similar digital solutions to transform agricultural trade:

- China's gxyj.com platform helps rural producers and consumers connect via online-to-offline systems. It offers services like logistics, payments, and quality certification. The Shouguang Vegetable Trading Market, China's largest of its kind, operates online and is supported by national modernization programs.

- East African Community Common Market (EACCM) and COMESA foster regional integration, promoting competitive pricing and limiting monopolistic practices. These markets benefit from standardized regulations, making product movement smoother and more reliable.
- Countries like Turkey and Ethiopia are also leveraging digital platforms to improve their agricultural marketing systems.
- India's e-NAM shares similar goals enhancing transparency, expanding access and improving farmer income through digital connectivity and better market integration.

Conclusion

The development of inclusive, adaptable and technology-driven markets is crucial for enhancing livelihoods, improving overall well-being and ensuring food security, especially for economically disadvantaged households. It is essential to take proactive steps toward the widespread implementation and adoption of e-NAM.

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HEALING THE EARTH; NUTRIENT MANAGEMENT THROUGH

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Abstract

Problem soils such as saline, sodic, acidic, and degraded soils—pose serious challenges to crop production due to poor physical structure, nutrient imbalance, and reduced biological activity. Reclamation of these soils is a crucial step not only in restoring soil health but also in enhancing nutrient use efficiency. This article explores how soil amendments like gypsum, lime, and organic matter can correct pH imbalances, improve soil texture, and release bound nutrients, making them more available to plants. Reclamation practices, when integrated with proper nutrient management strategies, can significantly boost crop yields, reduce input costs, and improve long-term soil fertility. By addressing soil constraints at the root, farmers can unlock the productive potential of marginal lands and contribute to sustainable agriculture.

Keyword: Problem soils, sodic, saline, soil management, nutrient, soil health.

Introduction

The dawn of new millennium poses tough challenges to the farming sector. because the population of India has crossed 1 billion. It is expected to cross 1.4 billion in the year 2025 and it is feared that it may even overtake China, if India's present population growth is not checked. To feed this burgeoning population, India needs to produce at least 301 M.t. in 2025.Not only the food grain production, the production of the other agricultural crops like cash crops and fibre crops is also necessary to raise the standard of living of Indian population, by increasing the export of agricultural products.

Adoption of improved management strategies, has undoubtedly increased the yield and productivity of crops over the years. However, in the last one decade, the magnitude of increase is decreasing due to the fact that the possible strategies have been exploited fully and that the key factors that contributed to green revolution are now blamed as agents of environmental degradation. Hence the productivity improvement will be possible only if greater attention is paid to the resource based, particularly soil, rather than, concentrating on modernized technologies.

Among the basic resources of agriculture, soil is the primary natural resource for any agricultural development and these soil resources are subjected to various kinds of and levels of degradation. A large area is also affected by specific problems of acidity, salinity, alkalinity, gullies and 22 Mha. is irreclaimable for agricultural uses. Hence identification of these constraints is a prerequisite before undertaking any measure towards nutrient management.

Identification of problem soils:

A soil which is found to possess almost all soil properties at its optimum proportion is considered to be a normal soil without any constraints, which is expected to produce to its maximum productivity. A normal soil is one which has got.

- Optimum texture *viz.*, loamy
- Optimum structure *viz.*, Crumby or granular
- Optimum infiltration rate
- Optimum hydraulic conductivity and permeability
- Optimum proportion of micro and macro porosity
- Optimum bulk density
- Optimum soil depth
- Proper aeration
- Neutral pH
- Non saline and non sodic
- Optimum CEC
- Optimum base saturation percentage
- Sustainable soil fertility
- Non pollution with industrial or any other pollutants.

A soil which has got either one or more of the above properties lacking is considered to be possessing a limitation which could result in low productivity of soils.

In general, the constraints limiting the crop production can be classified into

i. Constraints related soil physical conditions
ii. Constraints related soil chemical properties

Soil constraints related to soil physical properties:

Soil physical environment is the kingpin which regulate the retention and movement of soil moisture, soil erosion, soil nutrient movement, soil temperature, seed germination, seedling establishment, root penetration and proliferation etc. Hence soil physical environment directly and indirectly controls all the other factors that influence the plant growth and in turn the production potential of the crop.

In the recent years, attempts are being made under the fold of integrated nutrient management, organic farming and integrated farming system to increase the crop production under the rationalized plant nutrient management, where the management of physical condition plays a pivotal role. Judicious application of all nutrients at times failed to yield good results. It might be due to unforeseen weather conditions like heavy rain, stagnation of water, long dry spell or continuous cultivation which finally affects the soil physical environment like infiltration, moisture retention and transmission, soil compaction and aggregation leading to soil physical constraints constantly.

1. Excessive permeable soils / High permeable soils / Coarse textured soils:

Soil which possess the sand content exceeding 70 per cent are considered to be coarse textured soils and they exhibit the following characteristics.

- Sand content exceeding 70 per cent
- Low available water holding capacity
- High infiltration rates
- Excessive permeability
- Excess aeration porosity
- Heavy leaching losses of nutrients
- Rich in minerals like quartz, which is chemically inert

The reclamation of this soil is by compaction technology which means that the soil has to be rolled over with a stone roller of 400 kg on both the direction of the field.

The other management strategies are:

i. Provision of protective soil sub surface barrier of bitumen or asphalt sheet
ii. Application of liberal quantities of organic manures
iii. Incorporation of tank silt upto 100 t ha^{-1}
iv. Use of minimum and more frequent irrigations
v. Farming minimum plot size
vi. Adopting more number of splits for fertilizer application.

2. Heavy textured soils of soils with slow permeability:

The show permeable soils are characterized by

- Clay content exceeding 50 per cent
- Very low permeability
- Poor infiltration rate
- Low hydraulic conductivity
- Less than 15% of pores as macro pores
- Poor drainage
- High nutrient fixation
- Nutrient toxicities when continuously submerged

Reclamation of these sols involve:

- Provision of drainage open or sub-surface
- Addition of river sand or red loam soils up to 1 t ha^{-1}
- Contour bunding/Compartmental bunding to increase infiltration
- Addition of liberal quantities of organic manures
- Formation of ridges and furrows
- Formation of raised and sunken beds
- Formation of broad bed furrows
- Addition of soil conditioners-e.g. vermiculites, Jalasakthi.

3. Sub soil hard pan:

The soils with sub soil hard pan at shallow depth is mainly caused due to the illuviation of clay along with irrigation / rain water and deposition of the same at a shallow depth. When this washing was associated with the leaching of Fe and A1 hydroxides, the deposited clay are

cemented by these inorganic cementing agents, which are irreversibly dehydrated and thereby form hard pans. Such a hard pan formation at shallow depth not only restricts the root proliferation but also results in impeded drainage due to poor infiltration rate and hydraulic conductivity. It also results in the locking up of huge resources of fertilizer nutrient elements in that layer resulting in the permanent loss.

Reclamation of these types of soils are mainly by Chisel technology which is done by ploughing the field with a single tyned chisel plough at 50 cm intervals to a depth of 50 cm on both the directions of the field followed by disc ploughing twice. This result in the pulverization of the hard pan, and incorporation of organic manure sustain this favourable physical environment for a longer period of time.

4. Soil surface crusting:

Surface crusting mostly occurs in the red soil areas where the soil aggregates are weakly cemented by the colloidal oxides of iron and aluminium which are very weak when they are moist thereby resulting in the breaking up into single grained particulars after irrigation or rainfall. The resultant suspension, when settles, forms a thin layer of clay on the soil surface which upon drying leaves a hard crust on the soil surface which

- prevents germination of seeds
- retards/ inhibits root growth
- results in poor infiltration
- accelerates surface run off
- Creates poor aeration in the rhizosphere
- Affects nodule formation in leguminous crops.

The reclamation of surface crusted soils can be minimized by:

i. breaking up of the crust using a cultivator
ii. Addition of organic manures and lime to increase aggregate stability.
iii. Use of mulch
iv. Using bold sized grains to sowing
v. More number of seeds / hills
vi. Sprinkler irrigation, where ever possible

5. Fluffy paddy soils:

The traditional method of preparing the soil for transplanting rice consists of puddling,

which results in complete breakdown of soil aggregates into a uniform structure less mass. Repeated cultivation of rice does not allow the soil to rejunuvate its soil structure which results in the reduction of soil bulk density of < 1 Mg m^{-3}. Due to this the soil loses its anchorage and thereby the animals and labour sink into the puddled soil. The seedlings transplanted in such soil also float over the flood water due to poor anchorage.

Reclamation of this physical constraint is mainly by compaction technology wherein 400 kg store roller is passed over the soil at field capacity moisture 8-10 times on both the directions before shallow puddling of the soil. Furthermore, it is advised not to grow more than one paddy, which can be followed by a dry irrigated crop.

Soils with chemical constraints:

1.Acid soils:

Soil which are having high degree of adsorbed $A1^{3+}$ and H are called acid soils. These soils are characteristically present in the high rainfall region of cold climate where the bases are leached down the soil profile due to heavy leaching, leaving $Al^{3+}$and H^{+} in the surface soil. These soils are mostly derived from acid parent materials viz.. granite and rhyolite. The acidity, may also be due to the production of organic acids from the partial decomposition of organic matter due to cold climate. It may also be formed due to the addition of acid forming fertilizers like elemental sulphur, ammonium sulphate. ammonium chloride etc. The acid rains that can occur in the industrially polluted area can also acidify to the soils.

The acid soils pose the following problem to crop growth.

- H^{+} injury
- Fe, Al and Mn toxicity
- Growth of microorganisms restricted.

Management of the acid soils can be done by applying liming materials like

- Quick lime/Burnt lime / Oxide of lime
- Hydrated lime
- Lime/Calcite
- Dolomite
- Marl/Oyster shell / Basic stag

2. Saline Sodic Soils:

The EC of saline sodic soil is > 4.0 dS m^{-1}. pH of < or > 8.5 and the exchangeable sodium percentage of > 15%. The saline sodic soils are derived from the basic igneous rocks like basalt and sand stone and mostly occur in low rainfall areas. It is also concentrated in the areas where rainfall is less than evaporation. resulting in the upward movement of salts by capillarity. It is also resulted due to irrigation of poor-quality water, with no or poor drainage. The saline sodic soils can also occur in areas where the ground water is inundated with sea water.

The reclamation of saline sodic soil is done by adding calcium containing amendments like gypsum, calcium chloride, calcium carbonate phospho gypsum or calcium producing amendments like elemental S. sulphuric acid or pyrite. They are incorporated into the soil and the exchanged Na is removed by providing suitable drainage. Addition of green manure or green leaf manure increases the solubility of gypsum and enhances the reclamation process.

3. Saline soils:

The EC of saline soil is >4.0 dS m^{-1}. pH of <8.5 and the exchangeable sodium percentage of <15%. Saline soils contain excess amounts of water soluble ions to affect the crop growth adversely. The effects of saline sols are:

- White encrustation on the surface of soils.
- Absorption of water is impaired.
- The uptake of nutrient was retarded.
- The microbial activity is hampered.

The reclamation of saline soils can be undertaken by providing drainage facilities and leaching out the soluble salts by good quality water. The other management aspects are:

i) Growing salt resistant / tolerant crops

ii) Growing crops in raised bed, ridges and furrows

iii) Mulching to avoid raising of salts by capillarity.

iv) Addition of an extra dose of N.

v) Addition of organic manures.

vi) Alternate furrow irrigation

vii) Mixing with good quality water

viii) Drip/Sprinkler irrigation system.

4. Sodic soils:

Soils which are having high quantities of sodium in the exchange complex are called sodic soils. The characteristics of sodic soils are:

- pH > 8.5; EC <4 dS m^{-1} and ESP > 15%
- Dominant salts are CO_3 and HCO_3
- Dispersed clay resulting in poor percolation
- Total reduction in the microbial activity.
- Reduced availability of N, P, Fe and Zn.

The reclamation of sodic soils can be similar to the reclamation of saline sodic soils.

5. Acid sulphate soils:

Soil with enough sulphide (as FeS_2) become strongly acidic when drained are called acid sulphate soils. Before drainage, such soils may have neutral pH, hence called potential acid sulphate soils. The acid sulphate soils occur in lands inundated with water containing dominant proportions of sulphate, which when reduced to sulphides forms FeS_2 with iron. Upon drainage the pyrite is oxidized and farm sulphuric acid which reduces the pH of the soil below 4.0.

The characteristics of acid sulphate soils are

- pH value of <4.0 under aerobic conditions
- Yellow mottles of jarosite and deposits of ochre in the drainage water in soil
- The plants will have exaggerated water stress
- The soil will be very soft
- Continuous flooding result in the emission of hydrogen sulphide gas
- Precipitation of FeS_2 around the roots of paddy crop
- Deficiency of N, P, Zn and Mo.
- Toxicity of A1. Fe, Mn and H.

The reclamation of acid sulphate soil is by the addition of lime depending or the time requirement and leaching out the excess Al and H though open or sub surface drainage.

Conclusion

Reclaiming problem soils is not merely a corrective measure but a proactive strategy to enhance nutrient availability, crop productivity, and soil resilience. By addressing issues like salinity, sodicity, or acidity through appropriate amendments and cultural practices, farmers can

restore the natural balance of the soil and improve the efficiency of applied fertilizers. Integrated reclamation and nutrient management not only improve immediate crop performance but also ensure long-term sustainability of the land. Empowering farmers with knowledge and resources for soil reclamation is essential to transform underperforming soils into productive assets for food security and environmental health.

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ARTIFICIAL INTELLIGENCE REVOLUTIONIZES CHEMICAL USE IN AGRICULTURE

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Introduction

The world is facing challenges related to nutritional safety and environmental compatibility and the agricultural sector is exposed to a technological revolution driven by artificial intelligence (AI). Among many applications, AI has been developed as a powerful tool to reduce the use of chemicals in agriculture, particularly through innovative pesticide recognition and environmentally friendly degradation approaches. This revolution not only assurances to increase crop yields, but also targets to safeguard the environment and support improved ecosystems. However, this confidence has numerous disadvantages. This lead to degradation of soil, water pollution and loss to non-target species, containing beneficial insects and wildlife. Besides, unnecessary use of pesticides can lead to augmented pest resistance and is crucial to finding new sustainable answers. AI addresses some challenges linked to chemical usage in agriculture. They are as follows.

1. Pesticide Recognition:

Traditional monitoring methods for monitoring pests include a wide range of pesticide applications that can lead to unnecessary chemical use. Equipped with advanced imaging

technology, AI systems can analyse plants in real time and identify pest invasions at early stages. The identification of a particular problem allows farmers to use only targeted treatments when needed and that significantly reducing the overall use of pesticides.

2. Environmentally Friendly Disintegration:

Apart from pest detection, AI can play an significant role in the improvement of more environmentally friendly pesticides degradation methods. Investigators use AI control algorithms to recognize microbial strains that can divide detrimental chemicals into detrimental substances. This bioremediation method not only diminishes the quantity of detrimental constituents remaining in the environment, but also endorses healthier soils and plants.

3. Precision Agriculture:

AI progresses precision farming by analysing enormous data records from soil situations and weather predictions to harvest and market trends. This data allows farmers to make well-discovered verdicts about when and how much chemical input they must to practice. For instance, AI can optimize irrigation strategies and forecast pest outbursts to safeguard that chemicals are used conservatively and efficiently.

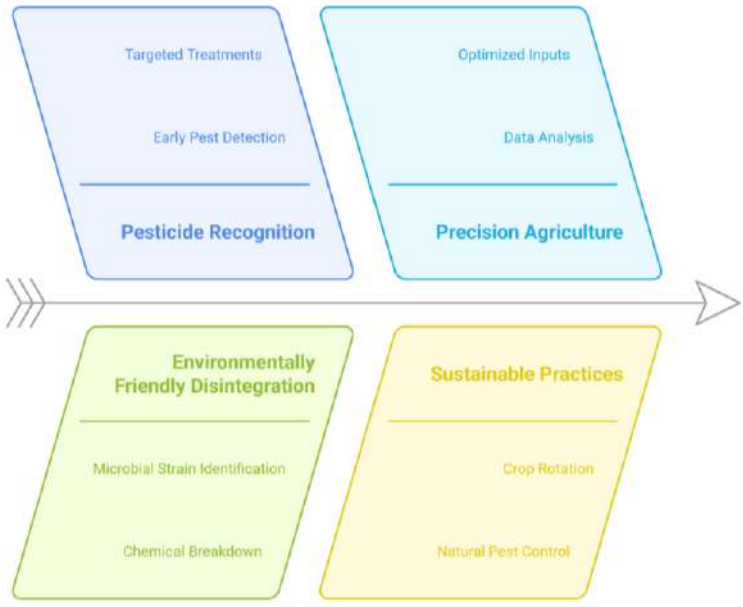

Fig. 1. AI solutions for reducing chemicals use in Agriculture

4. Sustainable Practices:

AI-supported management tools aid farmers use sustainable practices that diminish chemical dependency. For instance, AI can suggest a harvest alternation plan or an additional

planting approach. This decreases the need for chemical interventions by endorsing natural pest control approaches.

Impacts in real world

Start-ups and research organizations monitor pest population using drones and AI-controlled devices in the field, while machine learning algorithms forecast pest behaviour based on climatic conditions. This not only saves currency, but also contributes to healthier ecosystems. This not only assistances from the end results, but also progresses food supply security and reduces environmental effect.

Looking Forward

As technology is emerging, we can assume even more rigorous explanations that permit for dramatic declines in chemical use throughout the sector. Collaboration between technology inventors, agricultural professionals and political decision-making is enormously significant for knowledge of this possibility and guarantee of these inventions for farmers around the world.

Conclusion

Accepting these skills will take substantial steps to guarantee a healthy planet for upcoming generations. With AI at the top, the future of agriculture can be effectively and environmentally conscious, and new progressions can be set up to track sustainability.

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KETOSIS IN DAIRY CATTLE

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Introduction

Ketosis is a multifactorial metabolic disorder that occurs primarily in high-yielding dairy cows during early lactation. It arises due to negative energy balance (NEB), wherein the energy demand, particularly for milk production, exceeds the dietary energy intake. This mismatch leads to: Hypoglycemia, Ketonemia (elevated ketone bodies in blood: acetoacetate, β-hydroxybutyrate [BHB], and acetone) and Ketonuria

Occurrence

Ketosis typically develops during the first 2 months postpartum, with a peak incidence in the first 2 weeks after calving.

- 90% of cases occur within the first 60 days of lactation (10 to 28 days post-calving).
- Subclinical ketosis prevalence can be as high as 40% in undernourished or poorly managed herds.

The period between calving and peak lactation **is critical:**

- Cows are in NEB due to increased demand for glucose (for lactose synthesis).
- Despite reduced feed intake, hormonal stimulation maintains high milk production, aggravating glucose deficit.This triggers lipolysis, releasing non-esterified fatty acids (NEFAs) and increasing ketogenesis in the liver.

Risk Factors

1. Animal Factors

- Age and Parity:

- Risk increases with age.
- Peak incidence occurs around the fourth lactation.
- Primiparous cows (first-lactation) have lower incidence compared to multiparous cows.

- Body Condition Score (BCS):
  - Overconditioned cows (BCS > 3.25) at calving are at greater risk.
  - Significant loss in BCS (≥ 0.75) during early lactation increases risk.
- Previous History: Cows with prior ketosis episodes have more chance of recurrence.

2. Management Factors

- Feeding System:
  - Total Mixed Ration (TMR) systems show lower prevalence compared to component-fed herds.
- Dry Period Management: Prolonged dry periods or poor transition diets increase risk.
- Calving Complications:
  - Milk fever, retained placenta, twinning, lameness, hypomagnesemia, and metritis increase ketosis risk.
  - Displaced abomasum is both a cause and consequence of ketosis. Cows with high BHB in early lactation have increased odds (3–4x) of DA development.

3. Nutritional Risk Factors

- Negative Energy Balance (NEB): Due to inadequate DM intake during early lactation.
- Type of Feed: High butyrate silage (spoiled / high moisture ensilage) increases the risk.
- Deficiencies:
  - Cobalt deficiency impairs TCA cycle, causing ketosis.
  - Possible role of phosphorus deficiency.

4. Seasonal and Environmental Factors

- Seasonality:
  - Cows housed indoors during winter and spring months show higher ketosis incidence. Conversely, cows calving on pasture are at a lower risk.
- Herd Variation:
  - Due to differences in management, feeding practices, and genetic makeup

Clinical Signs

1. Wasting Form (Most Common)

- Gradual onset over 2 to 4 days.
- Reduced appetite, with a specific pattern:
- Initially refuses grain, then ensilage, but may continue to eat hay.
- Depraved appetite may occur (licking wood, soil).
- Rapid body weight loss and the cows may appear "woody" due to loss of subcutaneous fat and skin elasticity.
- Feces: Firm and dry, but not severely constipated.
- Normal temperature, pulse, and respiratory rate.
- Rumen motility: Decreased amplitude/number, especially in long-standing cases.
- Sweet odor of ketones (acetone) may be noted on: Breath and Milk
- Milk yield reduction by up to 25% and Milk solids-not-fat content decreases.

2. Nervous Form (Nervous Ketosis)

- Sudden onset, bizarre neurological behavior, suggestive of delirium:
    - Circling, leg crossing or straddling, head pressing, apparent blindness, aimless wandering and vigorous licking of skin or objects
- Hyperesthesia (sensitive to touch), tremors, tetany, and incoordination..

3. Subclinical Ketosis (Hyperketonemia)

- No visible clinical signs.Defined by:
    - ↑ BHB in blood, plasma, or serum
    - Ketonuria
- Cows in early lactation may show:
    - Reduced milk yield (by 1–9%)
    - Poor fertility: delayed estrus, endometritis, longer calving-to-conception interval, reduced conception at 1st AI.
- Urine dipstick tests (5–12 days postpartum) are more effective.

Diagnosis

A. Key Biochemical Findings

- Hypoglycemia:
    - Normal plasma glucose: 50–65 mg/dL
    - In ketosis: 20–40 mg/dL

- Ketonemia: Elevated β-hydroxybutyrate (BHB) is most reliable.
    - Normal: <1.0 mmol/L
    - Subclinical ketosis: >1.0–1.4 mmol/L
        - Week 1 postpartum cut-off: >1.0 mmol/L
        - Week 2 postpartum: >1.4 mmol/L
    - Clinical ketosis: >2.5 mmol/L
        - Can reach up to 10.0 mmol/L
- Peak BHB usually on day 8 postpartum.

  Urine and milk ketone detection: Less accurate than plasma but used cow-side.
    - Acetoacetate detection in urine is preferred using nitroprusside tests. Urine acetoacetate is superior to milk BHB for diagnosis.
    - Acetone only detected at >600 mmol/L.
    - BHB strip tests are available for milk.
    - Somatic Cell Count >1 million affects accuracy.
    - Fat ↑, Protein ↓ during NEB. Ratio >1.5 indicates the risk for ketosis.

B. Clinical Bio - Chemistry & Hematology

- Liver enzymes may be elevated.
- Rumen VFA: Butyrate increases disproportionately to acetate and propionate.
- Serum calcium may slightly decreased to ~9 mg/dL (2.25 mmol/L).

TREATMENT

1. Propylene Glycol

   300–500 mL orally once daily for 5 days

   Dextrose (Glucose)

   500 mL of 50% solution, IV, once (can repeat if needed)
2. Glucocorticoids

   Dexamethasone (e.g., 20–25 mg IM)
3. Vitamin B12 (Cyanocobalamin)

   1 to 4 mg, IV, daily for 2–6 days (often used in combination with butaphosphan)
4. Insulin (Protamine zinc insulin)

   200–300 IU, SC, once daily for 2–3 days (used in combination with steroids)

5. Isoflupredone Acetate

   20 mg IM, single dose only

   Repeated doses not recommended due to risk of hypokalemia

PREVENTION & CONTROL

1. Nutritional Management:

- Ensure balanced energy intake in both dry and lactating periods.Prevent the cows from being overconditioned or underfed at calving.
- Monitor:
  - Dry matter intake
  - Energy density
  - Fiber quality
  - Fat & protein levels
  - Particle size in feed
  - Feeding frequency and method (prefer total mixed ration over separate feeding)
- Avoid feeding:
  - Poor-quality silage (high butyrate)
  - Moldy/dusty hay
  - Old feed or sudden concentrate changes

2. Energy Supplements:

Propylene Glycol:

300–500 mL orally daily for 10 days post-calving

Can also be given 1 L/day for 9 days before calving

Glycerol:

1 L orally is effective but not effective when fed continuously in diet

Propionic Acid / Propionate Salts:

110 g/day, beginning at calving, for up to 6 weeks is effective but less palatable.

3. Monensin (Ionophore Antibiotic):

- Increases propionate production and reduces ketones
- Feeding:

  ➢ 11–22 g/ton of total mixed ration (dry matter basis)

➢ 185–660 mg/head/day for lactating cows

➢ 115–410 mg/head/day for dry cows

4. Rumen-Protected Choline:

- 15 g/day orally, from 25 days before calving to 80 days after calving.
- Supports fat metabolism and reduces clinical ketosis

5. Vitamin B12 (Cyanocobalamin) + Butaphosphan:

- Use in high-risk cows (older, fat, dystocia, metritis, etc.)
- 1–4 mg IV daily for 2–6 treatments around parturition

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MITOGEN-ACTIVATED PROTEIN KINASE (MAPK OR MAP KINASE) IN DEFENCE

Article ID: AG-V05-I08-76

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Introduction

Mitogen-activated protein kinase (**MAPK** or **MAP kinase**) is a type of serine/threonine-specific protein kinases involved in directing cellular responses to a diverse array of stimuli, such as mitogens, osmotic stress, heat shock and proinflammatory cytokines. They regulate cell functions including proliferation, gene expression, differentiation, mitosis, cell survival, and apoptosis.

MAP kinases are found in eukaryotes only, but they are fairly diverse and encountered in all animals, fungi and plants, and even in an array of unicellular eukaryotes.

MAPKs belong to the CMGC (CDK/MAPK/GSK3/CLK) kinase group. The closest relatives of MAPKs are the cyclin-dependent kinases (CDKs).

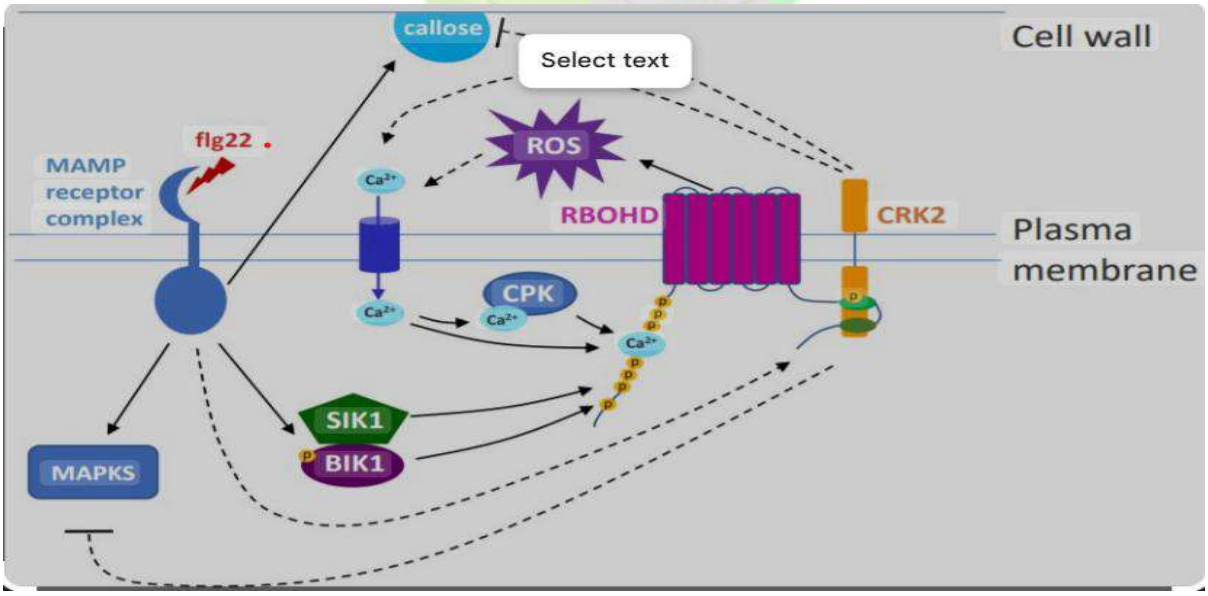


Fig 1. MAP kinase in fungi

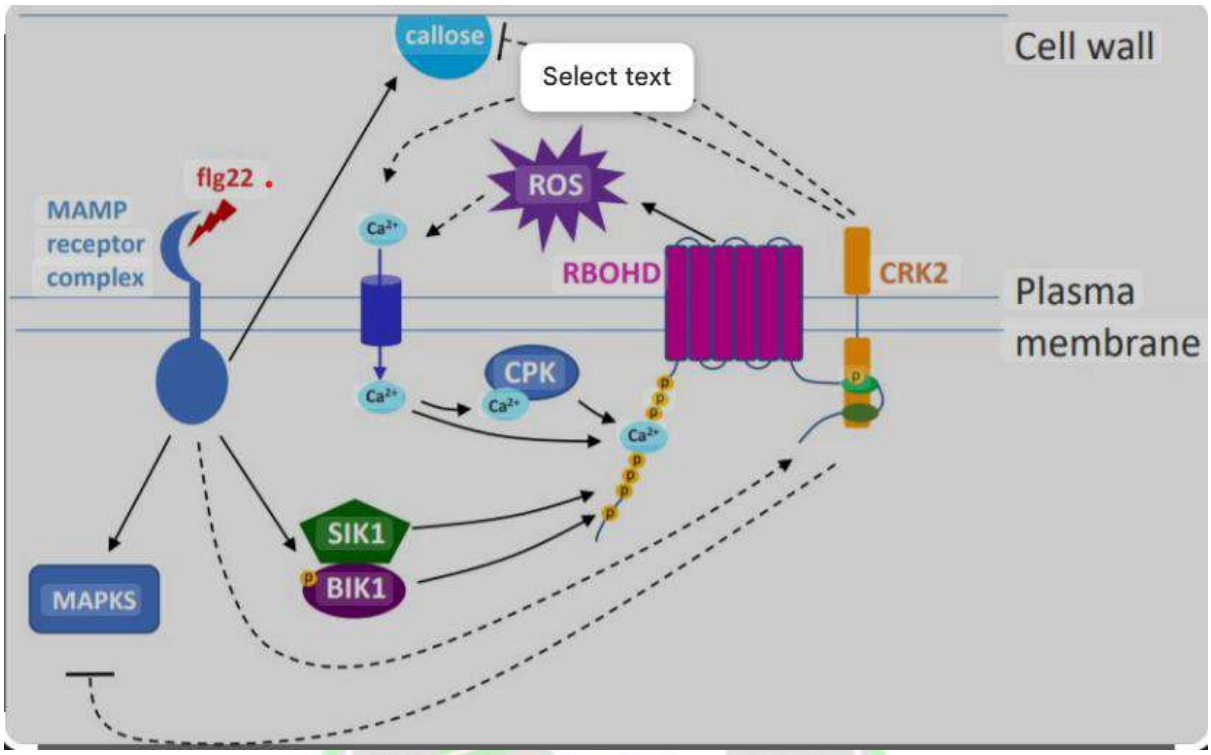
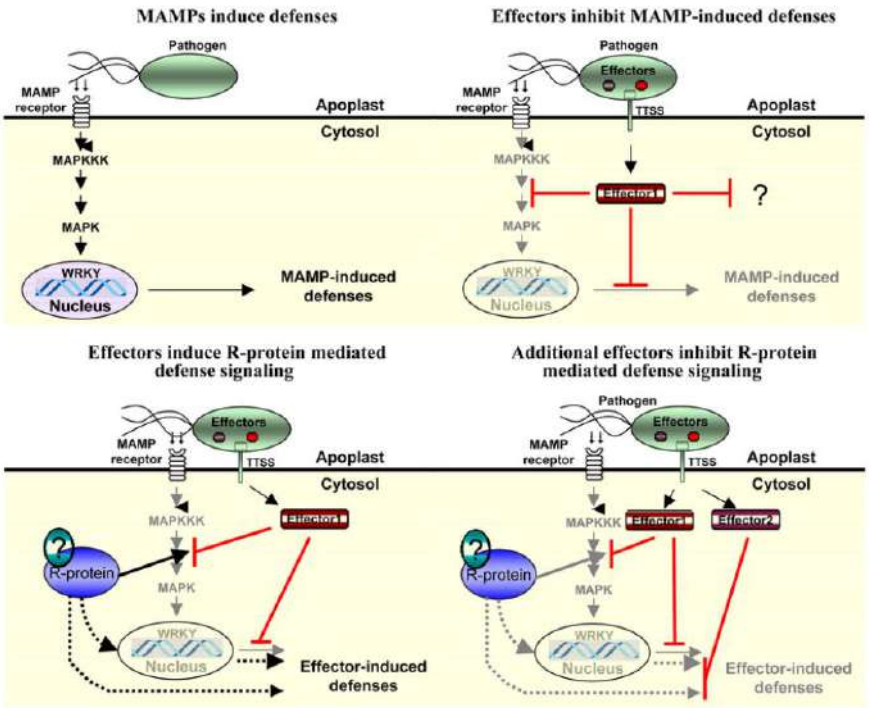


Fig 2. MAP kinase gram positive bacteria



Discovery

The first mitogen-activated protein kinase to be discovered was ERK1 (MAPK3) in mammals. Since ERK1 and its close relative ERK2 (MAPK1) are both involved in growth factor signaling, the family was termed "mitogen-activated". With the discovery of other members, even from distant organisms (e.g. plants), it has become increasingly clear that the name is a misnomer, since most MAPKs are actually involved in the response to potentially harmful, abiotic stress stimuli (hyperosmosis, oxidative stress, DNA damage, low osmolarity, infection, etc.). Because plants cannot "flee" from stress, terrestrial plants have the highest number of MAPK genes per organism ever found·Thus the role of mammalian ERK1/2 kinases as regulators of cell proliferation is not a generic, but a highly specialized function.

Types

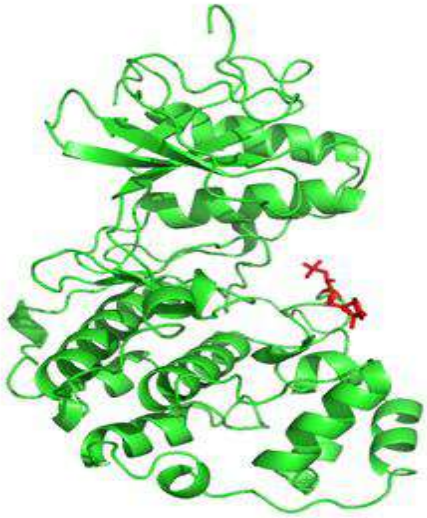
Most MAPKs have a number of shared characteristics, such as the activation dependent on two phosphorylation events, a three-tiered pathway architecture and similar substrate recognition sites. These are the "classical" MAP kinases. But there are also some ancient outliers from the group as sketched above, that do not have dual phosphorylation sites, only form two-tiered pathways, and lack the features required by other MAPKs for substrate binding. These are usually referred to as "atypical" MAPKs. It is yet unclear if the atypical MAPKs form a single group as opposed to the classical ones.

The mammalian MAPK family of kinases includes three subfamilies:

1. Extracellular signal-regulated kinases (ERKs)
2. c-Jun N-terminal kinases (JNKs)
3. p38 mitogen-activated protein kinases (p38s)

Generally, ERKs are activated by growth factors and mitogens, whereas cellular stresses and inflammatory cytokines activate JNKs and p38s.

X-ray structure of the ERK2 MAP kinase in its active form. Phosphorylated residues are displayed in red. Rendering based on pdb entry 2ERK.Mitogen-activated protein kinases are catalytically inactive in their base form. In order to become active, they require (potentially multiple) phosphorylation events in their activation loops. This is conducted by specialized enzymes of the STE protein kinase group. In this way protein dynamics can induce a conformational change in the structure of the protein via long-range allostery.



In the case of classical MAP kinases, the activation loop contains a characteristic TxY (threonine-x-tyrosine) motif (TEY in mammalian ERK1 and ERK2, TDY in ERK5, TPY in JNKs, TGY in p38 kinases) that needs to be phosphorylated on both the threonine and the tyrosine residues in order to lock the kinase domain in a catalytically competent conformation. In vivo and in vitro, phosphorylation of tyrosine oftentimes precedes phosphorylation of threonine, although phosphorylation of either residue can occur in the absence of the other.

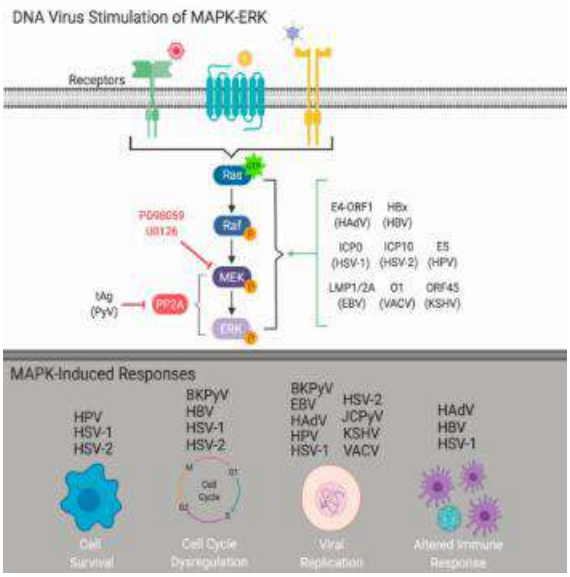


Fig 3. MAP kinase in virus

This tandem activation loop phosphorylation (that was proposed to be either distributive or processive, dependent on the cellular environment) is performed by members of the Ste7 protein kinase family, also known as MAP2 kinases. MAP2 kinases in turn, are also activated by phosphorylation, by a number of different upstream serine-threonine kinases (MAP3 kinases). Because MAP2 kinases display very little activity on substrates other than their cognate MAPK, classical MAPK pathways form multi-tiered, but relatively linear pathways. These pathways can effectively convey stimuli from the cell membrane (where many MAP3Ks are activated) to the nucleus (where only MAPKs may enter) or to many other subcellular targets.

In comparison to the three-tiered classical MAPK pathways, some atypical MAP kinases appear to have a more ancient, two-tiered system. ERK3 (MAPK6) and ERK4 (MAPK4) were recently shown to be directly phosphorylated and thus activated by PAK kinases (related to other MAP3 kinases). In contrast to the classical MAP kinases, these atypical MAPKs require only a single residue in their activation loops to be phosphorylated. The details of NLK and ERK7 (MAPK15) activation remain unknown.

Inactivation of MAPKs is performed by a number of phosphatases. A very conserved family of dedicated phosphatases is the so-called MAP kinase phosphatases (MKPs), a subgroup of dual-specificity phosphatases (DUSPs). As their name implies, these enzymes are capable of hydrolyzing the phosphate from both phosphotyrosine and the phosphothreonine residues. Since removal of either phosphate groups will greatly reduce MAPK activity, essentially abolishing signaling, some tyrosine phosphatases are also involved in inactivating MAP kinases (e.g. the phosphatases HePTP, STEP and PTPRR in mammals).

Signaling cascades

As mentioned above, MAPKs typically form multi-tiered pathways, receiving input several levels above the actual MAP kinase. In contrast to the relatively simple, phosphorylation-dependent activation mechanism of MAPKs and MAP2Ks, MAP3Ks have stunningly complex regulation. Many of the better-known MAP3Ks, such as c-Raf, MEKK4 or MLK3 require multiple steps for their activation. These are typically allosterically-controlled enzymes, tightly locked into an inactive state by multiple mechanisms. The first step en route to their activation consists of relieving their autoinhibition by a smaller ligand (such as Ras for c-Raf, GADD45 for MEKK4 or Cdc42 for MLK3). This commonly (but not always) happens at the cell membrane, where most of their activators are bound (note that small G-proteins are

constitutively membrane-associated due to prenylation). That step is followed by side-to-side homo- and heterodimerisation of their now accessible kinase domains. Recently determined complex structures reveal that the dimers are formed in an orientation that leaves both their substrate-binding regions free. Importantly, this dimerisation event also forces the MAP3 kinase domains to adopt a partially active conformation. Full activity is only achieved once these dimers transphosphorylate each other on their activation loops. The latter step can also be achieved or aided by auxiliary protein kinases (MAP4 kinases, members of the Ste20 family). Once a MAP3 kinase is fully active, it may phosphorylate its substrate MAP2 kinases, which in turn will phosphorylate their MAP kinase substrates.

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MICROPLASTICS AND HUMAN HEALTH: UNDERSTANDING THE RISKS AND PATH FORWARD

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Introduction

Plastics have become indispensable in modern society, with global production exceeding 320 million tons each year (Ragusa et al., 2021). Despite their usefulness, the durability of plastics has led to growing environmental problems. Large quantities of plastic waste accumulate in landfills, rivers, and oceans. Approximately 8 million tons of plastic debris enter the ocean annually (Mendoza & Balcer, 2019), where they degrade into smaller particles known as microplastics due to exposure to sunlight, mechanical stress, and microbial activity (Silva et al., 2018; Wang et al., 2021).

The issue of microplastics (MPs) gained attention as early as 1972, when researchers documented their increasing concentrations in the North Atlantic. Since then, the environmental and health concerns related to MPs have intensified. Initially thought to threaten only marine organisms, MPs have now entered the human food chain, raising urgent concerns about their effects on human health. Studies have found microplastics in human stool (Schwabl et al., 2019; Luqman et al., 2021), saliva (Huang et al., 2022), and even the placenta (Ragusa et al., 2021), indicating their pervasive presence and potential for bioaccumulation.

What Are Microplastics?

Microplastics are plastic fragments measuring less than 5 millimeters. They are classified into two types based on their origin:

1. Primary Microplastics

These are intentionally manufactured small plastics used in cosmetics, industrial processes, and personal care products. Common forms include:

- **Microbeads**: Often made from polyethylene (PE), polypropylene (PP), or polyethylene terephthalate (PET), these are used in toothpaste, face scrubs, and cosmetics for their abrasive properties.
- **Synthetic Fibers**: Found in clothing, carpets, and textiles, made from materials like polyester, nylon, and acrylic.
- **Plastic Pellets**: Used in manufacturing, these may enter the environment through spills or poor handling.

2. Secondary Microplastics

These result from the breakdown of larger plastic items due to environmental forces like sunlight, wave action, or abrasion. They include:

Microplastic Types and Forms

Characteristic	Primary Microplastics	Secondary Microplastics
Origin	Intentionally manufactured	Breakdown of larger plastics
Microbeads	Yes	No
Synthetic Fibers	Yes	No
Plastic Pellets	Yes	No
Fragmented Plastics	No	Yes
Weathered Surfaces	No	Yes
Degraded Films	No	Yes
Paint Flakes	No	Yes
Tire Particles	No	Yes

- Fragmented plastics
- Weathered plastic surfaces
- Degraded films
- Paint flakes
- Tire wear particles

Microplastics have been found in nearly every corner of the environment, including soil, freshwater, oceans, and even the air (Lamichhane et al., 2023). Their widespread distribution is largely due to improper waste management, industrial activity, and everyday plastic use.

Sources and Environmental Distribution of Microplastics

Estimates suggest that around 1.3 million tons of microplastics are released into oceans annually, a figure expected to rise to 3 million tons by 2040 if current trends continue (Tang, 2023). Coastal regions with higher population densities experience more severe microplastic pollution. Microplastics can reach aquatic environments from direct discharge, atmospheric fallout, and land based runoff (Apetogbor et al., 2023). Wind, rain, and UV radiation contribute to the breakdown of larger plastics, introducing even more MPs into freshwater systems (Viljoen et al., 2023).

How Do Microplastics Enter the Human Body?

Microplastic exposure in humans occurs mainly through ingestion, inhalation, and, to a lesser extent, skin contact.

Ingestion

Microplastics are commonly ingested via contaminated food and water. Seafood, especially filter-feeding shellfish, often contains MPs due to their presence in the marine food web (Kershaw & Rochman, 2015). More than 800 species have been documented to ingest plastic (Smith et al., 2018). MPs have also been found in honey, milk, beer, and salt (Liebezeit & Liebezeit, 2013; Li et al., 2022), likely due to contamination during processing and packaging.

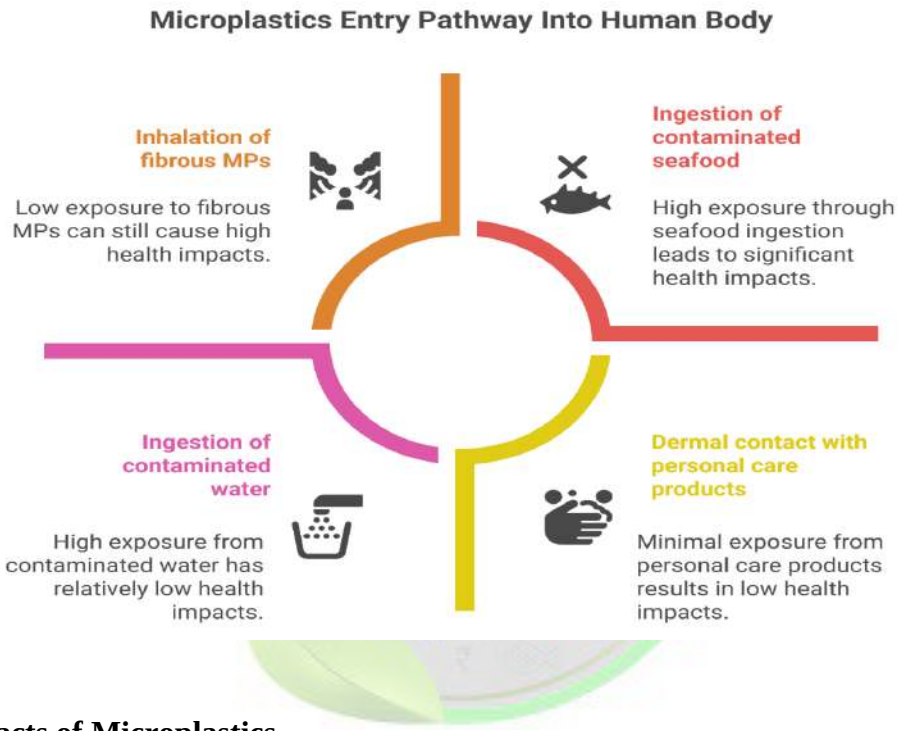
Inhalation

Airborne microplastics are found in both indoor and outdoor environments. Fibrous MPs from textiles, dust, or synthetic materials can be inhaled, especially those smaller than 5 μm in length and 13 μm in diameter (Gasperi et al., 2018). These particles may reach deep into the lungs and even be swallowed afterward (Vianello et al., 2019). Americans are estimated to

consume between 74,000 and 121,000 microplastic particles annually when inhalation is included (Cox et al., 2019).

Dermal Contact

Skin exposure to microplastics can occur through personal care products like scrubs or by washing in contaminated water (Revel et al., 2018). While the skin barrier prevents most MPs from penetrating, there is concern over smaller nanoplastics, which might bypass this barrier (Enyoh et al., 2020).



Health Impacts of Microplastics

Although the full extent of microplastic toxicity in humans is still being researched, studies point to several possible adverse effects.

1. Digestive Issues

MPs can disrupt gut health, leading to inflammation, altered gut microbiota, and increased intestinal permeability. Animal studies, especially in zebrafish, show mucosal damage, metabolic disturbances, and immune responses linked to MP ingestion (Qiao et al., 2019; Zhao et al., 2023).

2. Endocrine Disruption

Microplastics often carry endocrine-disrupting chemicals (EDCs) such as BPA, phthalates, and nonylphenol (Wee et al., 2022). These chemicals can interfere with hormone

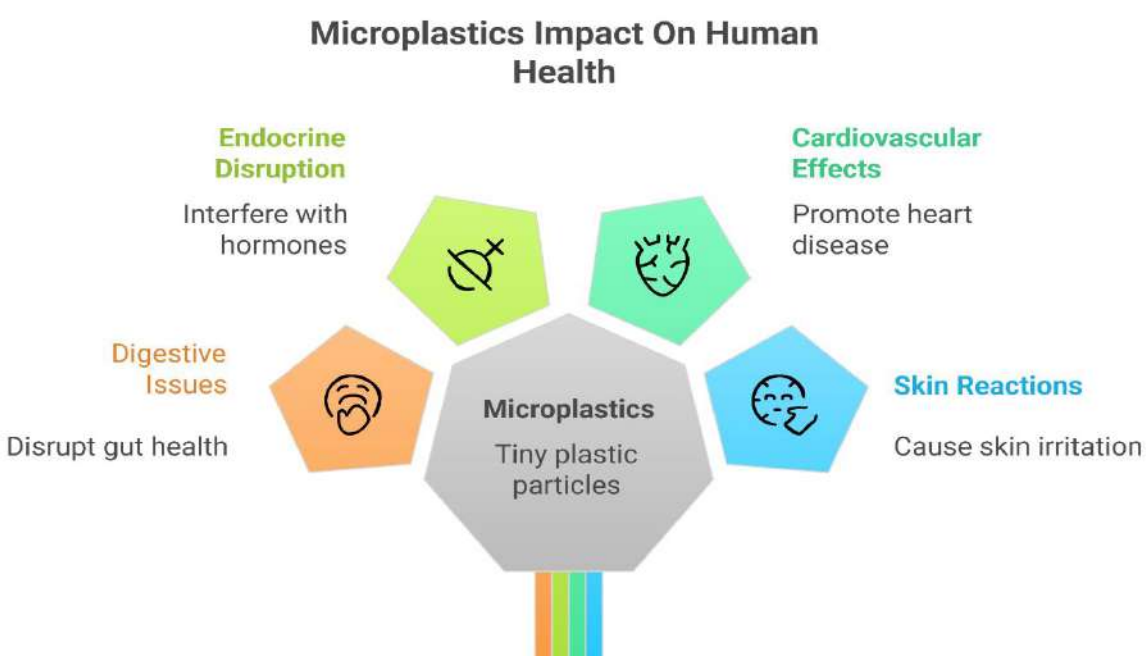
regulation, potentially affecting reproductive health, growth, and metabolism (Kontrick, 2018). In zebrafish, polystyrene microplastics increased reproductive damage when combined with microcystin-LR exposure, affecting hormone levels and fertility (Lin et al., 2023).

3. Cardiovascular Effects

Some studies indicate that MPs may contribute to cardiovascular disease by promoting inflammation, oxidative stress, and endothelial dysfunction (Persiani et al., 2023; Zhao et al., 2021). While findings in animal models are concerning, human health implications are still under investigation.

4. Skin and Immune Reactions

MPs can cause skin irritation, allergic responses, and possibly chronic inflammation with repeated exposure (Rahman et al., 2021; Tiwari et al., 2023). While a rat study showed no skin irritation with long-term PP microplastic exposure (Kim et al., 2021), smaller nanoplastics could behave differently.



Why Microplastics Are Dangerous Carriers

Microplastics pose additional risk because of their chemical characteristics. Their large surface area and hydrophobic nature allow them to absorb pollutants such as persistent organic pollutants (POPs)—including polychlorinated biphenyls (PCBs), PAHs, and organochlorine

pesticides (Andrady, 2011). When these pollutants bind to MPs, the toxic burden increases, especially if they are ingested or inhaled.

While macrophages and immune cells might respond to MPs, human cell lines like Caco-2 and HepG2 have not shown consistent toxicity in vitro (Jeon et al., 2021). This suggests a need for more mechanistic studies to fully understand how microplastics interact with human biology at the molecular level.

The Path Ahead: Research, Policy, and Public Action

Understanding the health implications of microplastics is critical. Future research should focus on:

- Long-term, low-dose exposure scenarios.
- Synergistic effects between MPs and environmental toxins.
- Effects on vulnerable populations, including children and pregnant women.

International policies like the OSPAR and HELCOM conventions have made progress in reducing marine microplastic pollution, but enforcement and global coordination remain limited. Raising public awareness is essential. Better waste management, consumer education, and regulations on plastic production and disposal can help curb the spread of microplastics (Ogunola et al., 2018).

Conclusion

Microplastics are no longer just an ocean issue they're quietly becoming a serious threat to our health and the health of the planet. From the fish we eat to the water we drink and even the air we breathe, these tiny plastic particles have found their way into nearly every corner of our lives. And they don't just sit there they can carry harmful chemicals and bacteria, potentially interfering with our hormones, triggering inflammation, and contributing to long-term health problems.

Science is still catching up to the full picture, but what we know so far is already alarming. We don't need to wait for all the data to act. It's time to update our laws to limit unnecessary plastic use, demand clearer labeling, and encourage companies to find safer, eco-friendly alternatives. But policies alone won't fix this people need to be part of the solution too. By making more mindful choices in what we buy and how we dispose of waste, we can all reduce our personal plastic footprint.

Microplastics aren't just an environmental concern they tie into bigger global issues like climate change, the loss of biodiversity, and environmental injustice. Communities near landfills or industrial zones, often low-income and underserved, are especially at risk of high microplastic exposure. That makes this not just a pollution problem but a social one too.

The good news? We still have time to turn things around. Scientists, governments, industries, and everyday people can all play a role. Investing in better materials, enforcing global agreements, and funding health-focused research will go a long way. And every effort no matter how small- adds up.If we ignore this problem, we risk letting microplastics become a permanent part of our environment and our bodies. But if we act now together we can protect the health of our planet and future generations. The solutions are within reach. We just have to care enough to make them happen.

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MILK FEVER

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Introduction

Synonyms: Parturient paresis, Hypocalcaemia

It is metabolic disease of adult females occurring most commonly about the time of parturition and characterized by hypocalcaemia, severe muscle weakness, sternal recumbency and lateral recumbency.

Etiology:

The principle cause of milk fever is a depression in the levels of ionized calcium in the extracellular space, including plasma which may be due to

1. Excessive loss of calcium in the colostrum and milk. The colostrum (approximately 2.3 g of Ca per kg) is rich in calcium
2. Decreased absorption of calcium from the intestine at the time of parturition
    a. Reduced feed intake at parturition
    b. Ruminal atony / indigestion
    c. Deficiency of Vit. D
    d. Improper calcium- phosphorus ration in the diet
    e. Diseases of intestine
3. Slow mobilization of calcium from the bone
    a. Parathormone deficiency
    b. Excessive calcium intake during dry period depresses the activity of PTH

Clinical signs

I. **First stage or stage of excitement**

- Cow is still standing
- Excitement, Nervousness
- Tetany
- Hypersensitiveness
- Muscle tremors of head and limbs
- Ataxia
- Shaking of head, Protrusion of tongue and Grinding of teeth
- Disinclined to move and often has a decreased or no feed intake
- Agalactia, rumen stasis, and scant feces
- Heart rate and respirations may be within normal limits or slightly elevated
- Skin of the animal – Cool to touch

II. **Second stage or stage of sternal recumbency**

- Animal is unable to stand and rests on sternum with head turned towards shoulder or flank
- Drowsiness
- Cold skin and extremities, dry muzzle and the rectal temperature subnormal (36 to 38° C, 97 to 101° F).
- Ruminal stasis and secondary bloat are common, and constipation is characteristic.
- Dilatation of pupil with absence of papillary light reflex
- Relaxation of anus with loss of anal reflex
- Heart sounds muffled, tachycardia (about 80 bpm).
- Suspended defecation and urination
- Low venous pressure, making it difficult to raise the jugular veins.

III. **Third stage or stage of lateral recumbency**

Characterized by severely obtunded or even comatose cow in lateral recumbency.

- Animal is unable to stand or sit and remains in lying down condition
- Markedly subnormal body temperature

- Heart sounds are almost inaudible, and the rate is increased up to 120 bpm
- Extremely cold skin with inaudible heart sounds
- Bloat- because of prolonged rumen stasis and lateral recumbency
- Impossible to raise the veins

Concurrent Hypomagnesemia

Mild to moderate tetany and hyperesthesia persisting beyond the first stage suggests a concurrent hypomagnesemia

Diagnosis

- History of parturition and high milk yield
- Symptoms:

  Ataxia, Muscle tremors, Tachycardia, sternal or lateral recumbency with subnormal body temperature
- Clinical pathology:

  Serum calcium levels: Levels of ionized Ca in the venous whole blood of cows are as follows:

  1. Normal = 1.06 to 1.26 mmol/L (4.3 to 5.1 mg/dL);
  2. Slight hypocalcemia = 1.05 to 0.80 mmol/L (4.2 to 3.2 mg/dL)
  3. Moderate =0.79 to 0.50 mmol/L (3.2 to 2.0 mg/dL)
  4. Severe hypocalcemia, less than 0.50 mmol/L (< 2.0 mg/dL)

Serum magnesium levels are usually moderately elevated to 1.65 to 2.06 mmol/L (4 to 5 mg/dL)

- Serum Muscle Enzyme Activity

  Prolonged recumbency results in ischemic muscle trauma and necrosis and increases in the serum muscle enzyme activity of creatine kinase (CK) and aspartate aminotransferase (AST)
- Hemogram

  Eosinopenia, neutrophilia, Lymphopenia, high plasma cortisol levels and increased PCV

Differential diagnosis

a. Other metabolic diseases (Hypomagnesemia, Hypophosphatemia and Severe hypokalaemia, Ketosis)

b. Diseases associated with toxaemia and shock (Acute or per acute coliform mastitis, Aspiration pneumonia, Acute diffuse peritonitis, Carbohydrate engorgement (grain overload) , Toxaemic septic metritis)
c. Injuries to the pelvis and pelvic limbs
d. Degenerative myopathy
e. Downer-cow syndrome

Treatment

- IV with solutions containing Ca as Ca- gluconate, Ca-borogluconate, and now a days less commonly—as Ca-chloride is the treatment of choice.
- Underdosing increases the chances of incomplete response, with inability of the cow to rise, or of relapse, whereas considerable overdosing may result in potentially fatal cardiac toxicity
- Calcium gluconate (equivalent to 8 to 12 g Ca/cow) IV or SC as single dose
- Calcium borogluconate (equivalent to 8 to 12 g Ca/cow) IV or SC as single dose (500 mL of 23% Ca-borogluconate by slow IV injection)
- Calcium chloride (equivalent to 8 to 12 g Ca/ cow) IV as single dose
- Calcium chloride (equivalent to 50 g Ca/cow) PO
- Calcium propionate (equivalent to 50 g Ca/ cow) PO

Complications of milk fever

- Prolapse of the uterus
- Aspiration pneumonia secondary to regurgitation and aspiration of rumen contents is a complication of third-stage milk fever
- Higher risk of Dystocia , Retained placenta , mastitis and displaced abomasum

Prevention and Control

Strategies for prevention of hypocalcaemia:

As cases of hypocalcemia immediately after calving may be as high as 50% among second- or third-lactation cows, it is important to act preventively to keep potential milk fever from developing.

- The cows must be enabled to quickly release calcium from the bones after calving, or they must be supplied with calcium that can be easily metabolized.

Upfront prophylaxis

- An energy and protein oversupply during the dry period should be avoided. In addition, an application of Vitamin D3 at the end of the pregnancy makes sense.
- To stimulate the active regulatory mechanisms of calcium metabolism, the calcium content in the feed should be reduced three to four weeks before calving. In practice, however, this often is not properly observed and feed with a relatively high calcium content is still given out during this period.
- To protect the cow from milk fever around calving, oral administration of calcium salts is widespread in practice. Vitamin D also plays a central role in calcium metabolism. It ensures that the absorption of calcium from the intestines and bones is increased.

1. Reduction of dietary Ca available for intestinal absorption during the dry period
    - Calcium-to-Phosphorus Ratio in Diet
    - Binding Dietary Calcium

    Feeding a calcium binder such as sodium aluminosilicate (zeolite A) before calving mimics a calcium deficiency and decreases the risk for parturient paresis.
2. Induction of Mild to Moderate Acidosis During Late Gestation: Dietary Cation–Anion Difference (DCAD)
3. Supplementation of vitamin D during the dry period
4. Oral Ca supplementation around parturition
5. Parenteral Ca administration around parturition
6. Partial milking

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NANOTECHNOLOGY IN AQUACULTURE: INNOVATIONS FOR A BLUE REVOLUTION

Article ID: AG-V05-I08-79

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Abstract

Nanotechnology is emerging as a transformative tool in aquaculture, addressing persistent challenges such as disease outbreaks, inefficient nutrient utilization, environmental pollution, and water quality deterioration. This review summarizes the key applications of nanotechnology in aquaculture, including nanobased drug delivery systems, nano-encapsulated feeds, nanobiosensors for water quality and pathogen monitoring, and nanomaterials for water treatment and disinfection. The integration of nanotechnology enhances productivity, ensures environmental sustainability, and supports the development of precision aquaculture practices. However, knowledge gaps remain regarding nanoparticle toxicity, bioaccumulation, and regulatory oversight, necessitating further research and risk assessments. This article critically reviews the current status, potential applications, and future directions of nanotechnology in aquaculture.

Introduction

Aquaculture, the fastest-growing food production sector globally, is increasingly challenged by environmental degradation, disease outbreaks, and the inefficiency of conventional production methods. Nanotechnology, the manipulation of materials at the nanoscale (1–100 nm), offers novel solutions by enhancing feed efficiency, diagnostics, drug delivery, and environmental monitoring (Fajardo et al., 2022a; Nasr-Eldahan et al., 2021a). This review explores the potential of nanotechnology to revolutionize aquaculture by integrating precision, sustainability, and productivity.

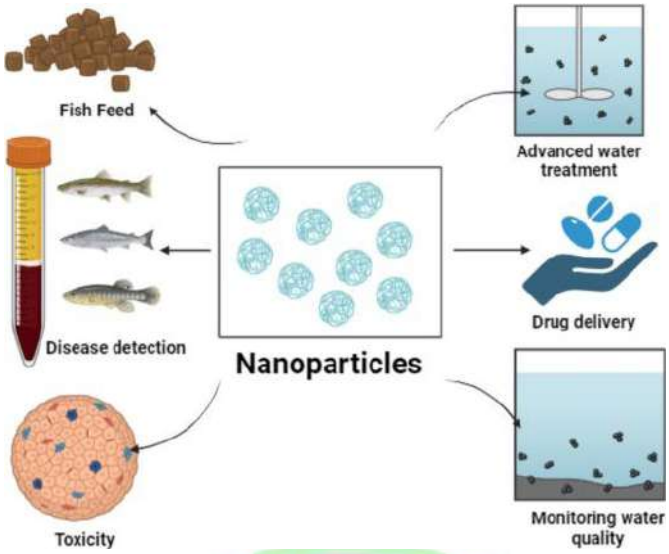

Figure 1 : Application of Nanomaterials in Aquaculture

Nanotechnology and Nano-Formulations in Aquaculture

Nanomaterials, including metal nanoparticles, nanoemulsions, and nanocomposites, are used in aquaculture for their unique properties such as high surface area, reactivity, and functionalization potential. Key nanotechnology platforms include:

Nanosilver (AgNPs): Antibacterial and antifungal properties.

Nanochitosan: Biocompatible carrier for drugs and nutrients.

Zinc oxide (ZnO) nanoparticles: Antioxidant and growth-promoting effects.

Nanoclay and nano-silica: Water purification and toxin adsorption.

These materials can be integrated into various applications such as feed, water systems, diagnostics, and therapeutics (Barreto et al., 2011; Emamifar et al., 2011).

Nano-Encapsulated Nutrients and Feed Additives

Nano-encapsulation improves the stability, bioavailability, and targeted delivery of essential nutrients. Nano-encapsulated vitamins, minerals, and probiotics enhance digestion, immunity, and growth rates in fish and shrimp (Zhou et al., 2018). For example, nano-selenium supplementation improves antioxidant enzyme activities, promoting fish health and resistance to stress. Additionally, nanoemulsions can deliver omega-3 fatty acids more efficiently, while nanochitosan acts as a carrier for phytogenic compounds, improving feed palatability and gut health (Abd El-Hack et al., 2021).

Nanotechnology in Disease Diagnosis and Drug Delivery

Disease is a major bottleneck in aquaculture. Nanotechnology offers rapid, sensitive, and non-invasive diagnostic tools through nanosensors and nano-biosensors:

- Quantum dots and gold nanoparticles (AuNPs) serve as markers for detecting pathogens such as Vibrio spp. And Aeromonas hydrophila (Liu et al., 2020).
- Nanobiosensors detect DNA, RNA, proteins, or metabolites linked to diseases, enabling real-time disease surveillance.
- For therapeutics, nano-drug delivery systems improve drug solubility, reduce side effects, and enable sustained release. For instance, nanochitosan-loaded antibiotics enhance treatment efficiency at lower doses, reducing antibiotic resistance development (Parisi et al., 2015).

Nanomaterials for Water Quality Management

Water quality is crucial for aquaculture health. Nanomaterials are used to detect and remove pollutants such as heavy metals, ammonia, nitrates, and pathogens. Carbon nanotubes (CNTs) and graphene oxide adsorb toxins and improve filtration efficiency. Nano-iron oxides and ZnO nanoparticles degrade organic pollutants and reduce chemical oxygen demand (COD).

TiO_2 nanoparticles act as photocatalysts for disinfection under UV light.These technologies are integrated into smart nano-enabled filtration and recirculating aquaculture systems (RAS) for enhanced environmental control (Fajardo et al., 2022b).

Antimicrobial and Antifouling Nanomaterials

Biofouling is a major issue in aquaculture equipment. Coatings embedded with nanosilver, copper nanoparticles, and ZnO nanoparticles offer long-lasting antimicrobial and antifouling properties, increasing the lifespan of nets, tanks, and pipes.

Nanocomposite-based paints and polymer films are being tested for use in cages and tanks, particularly in marine environments where fouling by algae, barnacles, and biofilms is prevalent (Rai et al., 2009).

Nanotechnology in Genetic and Reproductive Technologies

Emerging uses of nanotechnology include gene delivery and reproductive enhancement:

Nanocarriers for DNA and RNA delivery (e.g., siRNA or CRISPR-Cas9 systems) are being developed for genetic improvements such as disease resistance and growth traits.

Magnetic nanoparticles assist in sorting sperm cells or concentrating gametes, enhancing fertilization in hatcheries (Wang et al., 2022).

These technologies remain largely experimental but show potential for transformative breeding programs.

Risk Assessment and Nanotoxicology

Despite promising applications, the environmental and health risks of nanomaterials must be thoroughly evaluated. Nanoparticles can:

- Accumulate in aquatic organisms, posing toxicity to gill, liver, and reproductive tissues.
- Disrupt microbiota and aquatic ecosystems.
- Enter the food chain and pose risks to human consumers.

Long-term ecotoxicological studies and standardized risk assessment protocols are needed (Sundaram et al., 2016; Handy et al., 2011).

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METAGENOMICS: A NEW ERA IN MICROBIAL RESEARCH AND BIOTECHNOLOGY

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Abstract

Metagenomics is a groundbreaking approach that enables the direct analysis of genetic material from environmental samples, bypassing the need for traditional culturing methods. This technique allows researchers to investigate the composition, structure, and function of entire microbial communities, including previously unculturable organisms. The workflow of metagenomics involves key steps such as sampling, DNA extraction, sequencing, assembly, binning, annotation, statistical analysis, and data sharing. Metagenomic studies are broadly classified into structural and functional approaches, each providing unique insights into microbial diversity and activity. With applications in environmental monitoring, bioremediation, clinical diagnostics, agriculture, and industrial biotechnology, metagenomics is reshaping our understanding of the microbial world. Advancements in sequencing technologies, bioinformatics, and AI-driven tools are expected to further expand its potential, making it a vital tool for future scientific discovery and innovation.

Key words: Bioinformatics, environment, microorganisms, metagenomics, sampling.

Introduction

Metagenomics, often described as the study of genetic material recovered directly

from environmental samples, has revolutionized our understanding of the microbial world. Unlike traditional microbiology, which relies on culturing microorganisms in the lab—a method that fails to capture over 99% of microbial diversity—metagenomics allows for the comprehensive analysis of entire microbial communities, including unculturable species. By using advanced sequencing technologies and bioinformatics tools, scientists can now explore microbial diversity, population structures, evolutionary relationships, and functional potential in a variety of ecosystems. This powerful approach has found widespread applications in environmental science, medicine, agriculture, and biotechnology, offering unprecedented insight into the invisible but vital world of microbes. (Zhang *et al*., 2021)

The direction of metagenomics study

Metagenomic studies are broadly categorized into two main types: structural metagenomics and functional metagenomics, each offering unique insights into microbial communities and their capabilities. Structural metagenomics focuses on understanding the composition and organization of microbial communities in an environment. It involves techniques such as DNA sequencing, assembly, binning, and taxonomic profiling to analyse the diversity, phylogeny, and potential metabolic pathways of microbes without culturing them. This approach is fundamental for ecological studies aiming to answer the question: *"What microorganisms are present in a given environment?"*

On the other hand, functional metagenomics seeks to discover and characterize genes that encode proteins with specific biochemical functions, especially enzymes. This method bypasses the need for culturing by directly cloning environmental DNA into expression vectors, followed by screening for activity. It is particularly useful for biotechnological applications, such as identifying novel enzymes that may be used in industry or medicine. Functional metagenomics addresses the question: *"What are these microorganisms doing?"* Both approaches complement each other and are integral to fully understanding the structure and function of microbial ecosystems. (Prayogo *et al*., 2020)

Typical metagenomic workflow:

1. Sampling and DNA Extraction

The first and foundational step in metagenomics is sample collection and DNA extraction. The primary objective here is to obtain high-quality, representative DNA from all microorganisms in a given environment—be it soil, water, or host-associated habitats. Various

protocols are used depending on the sample type. For host-associated microbiota, selective lysis or fractionation helps minimize host DNA contamination. For environmental samples like soil, methods are optimized to handle enzymatic inhibitors such as humic acids. DNA yield can be a challenge with low-biomass samples (e.g., biopsies or groundwater), where techniques like Multiple Displacement Amplification (MDA) are employed to amplify DNA, though they may introduce bias or artifacts.

2. Sequencing

Once sufficient DNA is extracted, the next phase is sequencing. Traditionally, Sanger sequencing was used due to its accuracy and long read lengths, but now next-generation sequencing (NGS) platforms dominate. Among these, 454/Roche pyrosequencing and Illumina are the most widely used. 454 offers longer reads (600–800 bp), which benefit assembly and annotation, whereas Illumina provides high-throughput, short-read sequencing (typically 150 bp), making it more cost-effective. While newer platforms like Ion Torrent, PacBio, and SOLiD are emerging, their applicability in metagenomics varies based on read length, throughput, error profile, and cost.

3. Assembly

Sequence assembly aims to reconstruct longer DNA contigs from short reads. This is crucial if the goal is to recover near-complete genomes or full-length genes. Two major strategies exist: reference-based assembly, which aligns reads to known genomes, and de novo assembly, which doesn't require a reference and is essential for novel organisms. Tools like Velvet, SOAP, and Meta Velvet are used for assembly, but challenges remain due to the complex, non-clonal nature of microbial communities. Specialized assemblers (e.g., Meta-IDBA) have been developed to handle these complexities better.

4. Binning

Following assembly, binning sorts the contigs or reads into clusters representing individual or closely related genomes. Binning is done using compositional features (like GC content and k-mer frequencies) or similarity-based approaches (alignment to reference genomes). Tools like PhyloPythia, MEGAN, and PhymmBL combine these methods. Longer contigs typically yield more accurate taxonomic assignments, and having robust reference databases is key for high-resolution binning.

5. Annotation

Annotation provides biological context to the assembled and binned sequences. It begins with feature prediction—identifying genes (coding and non-coding)—using tools such as FragGeneScan, MetaGene Mark, or Metagene Annotator. Next comes functional annotation, which matches genes to known databases like KEGG, eggNOG, and COG. Annotation remains a major bottleneck because a large proportion of sequences cannot be mapped to any known function, resulting in "ORFans" (genes with no known homologs). Improving annotation accuracy requires both enhanced algorithms and expanded reference libraries.

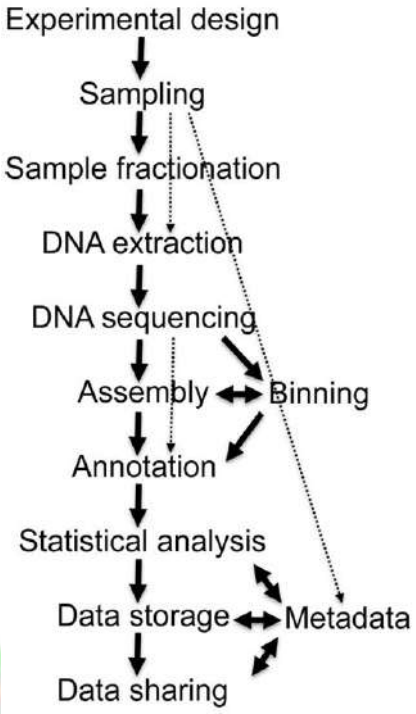

Fig 1: Flow diagram of a typical metagenome project. (Dashed arrows indicate steps that can be omitted.)

6. Statistical Analysis and Experimental Design

Proper experimental design and statistical analysis are essential for drawing meaningful ecological or functional conclusions from metagenomic data. Experimental variables, replication, and control samples must be carefully considered. Data are often structured as matrices (e.g., taxon/sample or function/sample), enabling multivariate statistical analysis. Tools like PRIMER-E, Metastats, and Shotgun FunctionalizeR help identify patterns and significant differences between sample groups. Temporal and spatial sampling, technical variation, and sequencing depth must be addressed to ensure reproducibility and statistical power.

7. Data Storage and Sharing

With massive volumes of data generated, data storage and sharing is a key step in metagenomics. Repositories like MG-RAST, IMG/M, and CAMERA provide pipelines for analysis, annotation, and visualization, while supporting community standards for metadata like MIxS (Minimum Information about any (x) Sequence). Shared platforms facilitate comparative studies and reduce the need for re-analysis. Efforts are ongoing to compress and optimize storage formats to manage the ever-growing size of metagenomic datasets efficiently. (Thomas *et al*., 2012)

Applications of Metagenomics

Metagenomics has a wide array of applications across several domains due to its ability to analyse entire microbial communities without the need for cultivation. Here's a brief overview of its major applications:

1. Environmental Studies

Metagenomics is extensively used to assess microbial diversity in various environments such as soil, oceans, glaciers, and extreme habitats. It helps identify novel microorganisms, explore their roles in nutrient cycling (like carbon, nitrogen, and sulphur), and discover new enzymes with industrial potential.

2. Bioremediation

Metagenomics aids in identifying microbial genes and communities involved in the degradation of environmental pollutants like hydrocarbons, pesticides, plastics, and heavy metals. This facilitates the development of microbial strains or consortia for effective bioremediation of contaminated soils and water bodies.

3. Medical Diagnostics

In clinical settings, metagenomics is revolutionizing pathogen detection, especially for infections where traditional culture methods fail. It enables rapid and comprehensive identification of bacteria, viruses, fungi, and parasites directly from clinical samples. It's also used to monitor antibiotic resistance genes (ARGs) and study the gut microbiome's role in diseases like liver disorders, autoimmune conditions, and cancers.

4. Agriculture

Metagenomics helps explore the soil microbiome's role in crop productivity, disease suppression, and plant health. It also facilitates the identification of beneficial microbes and biocontrol agents that can be applied to promote sustainable agriculture.

5. Industrial Biotechnology

Through functional metagenomics, novel biocatalysts and enzymes are discovered from uncultured microbes. These enzymes are useful in pharmaceuticals, food processing, biofuels, and biodegradable plastic production. (Nam *et al*., 2023)

The Future of Metagenomics

Metagenomics holds immense potential for future scientific and technological advancements. With ongoing improvements in sequencing technologies and bioinformatics,

metagenomics is expected to uncover a vast number of previously unidentified microbial species and functional genes. This could lead to the discovery of novel enzymes, antibiotics, and other bioactive compounds valuable for biotechnology, medicine, and agriculture. Moreover, metagenomics may revolutionize disease diagnostics, therapeutic development, and personalized medicine by enabling detailed characterization of human microbiomes. In environmental science, it offers promising solutions for bioremediation and ecosystem monitoring. Integrating artificial intelligence with metagenomic data analysis, such as seen in the ESM Metagenomic Atlas, is anticipated to accelerate discoveries and unlock hidden aspects of microbial life. (Nam *et al*., 2023)

Conclusion

Metagenomics has emerged as a transformative tool in microbial research, enabling the comprehensive study of entire microbial communities without the need for cultivation. By combining advanced sequencing technologies with powerful bioinformatics, it provides deep insights into microbial diversity, functions, and interactions across various ecosystems. From environmental monitoring and bioremediation to medical diagnostics and industrial innovation, metagenomics has wide-ranging applications. As technology continues to evolve, especially with the integration of artificial intelligence, the future of metagenomics holds immense promise for uncovering new biological insights and driving scientific breakthroughs in health, agriculture, and biotechnology.

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PRECISION AGRICULTURE THROUGH NOVEL MOLECULES

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Abstract

Sustainable crop management has emerged as a pivotal concept in modern agriculture to ensure productivity while preserving environmental integrity. Traditional agrochemicals, though effective, often result in ecological imbalance, pest resistance, and health concerns. Recent advancements have led to the development of new-generation molecules that are more target-specific, environmentally friendly, and compatible with integrated pest and disease management strategies. This chapter explores the discovery, classification, modes of action, and applications of novel molecules including biopesticides, RNAi-based products, nanomaterials, and plant-derived bioactive compounds. Their role in enhancing crop resilience, reducing agrochemical load, and promoting soil health is discussed, supported by current research and field-level findings.

Introduction

Sustainable agriculture aims to maintain high crop productivity while minimizing environmental harm. Over the years, the excessive use of conventional agrochemicals has led to several challenges, including pest resistance, soil and water contamination, and health hazards. These issues have raised concerns about the long-term viability of traditional crop protection methods. To address this, researchers are developing **new molecules** that offer targeted, eco-friendly, and efficient alternatives. These include **biopesticides, RNAi-based products, nanoparticle formulations**, and **plant defense activators**. Unlike conventional chemicals, these molecules often degrade quickly, act specifically on target organisms, and are compatible with

integrated pest and disease management systems. Advancements in biotechnology, nanotechnology, and molecular biology have accelerated the discovery and application of such molecules, which play a vital role in promoting crop resilience, reducing chemical inputs, and supporting sustainable farming practices.

Limitations of Traditional Agrochemicals

Despite their significant role in increasing agricultural productivity, traditional agrochemicals pose several limitations that challenge the sustainability of modern farming systems:

1. **Environmental Pollution:** Excessive and repeated use of chemical pesticides and fertilizers leads to contamination of soil, groundwater, and surface water. This affects aquatic ecosystems and soil microbial diversity.
2. **Development of Resistance:** Continuous exposure to the same class of pesticides or fungicides results in the evolution of resistant strains of pests, pathogens, and weeds, reducing long-term efficacy.
3. **Non-Target Effects:** Broad-spectrum agrochemicals often harm beneficial organisms such as pollinators, natural enemies of pests, and soil microbes, disrupting ecological balance.
4. **Residue Accumulation:** Persistent chemical residues on crops pose serious health risks to consumers and may hinder export potential due to strict residue limits in international markets.
5. **Human and Animal Toxicity:** Prolonged or accidental exposure can cause acute or chronic health problems in farmers, farm workers, and animals, especially in the absence of proper safety measures.
6. **Declining Soil Health:** Chemical overuse leads to reduced organic matter, microbial imbalance, and soil acidification or salinization, adversely affecting soil fertility and crop productivity over time.
7. **High Input Cost:** Dependence on synthetic chemicals increases the cost of cultivation and reduces profit margins, particularly for smallholder farmers.

Hence, there's a growing shift toward safer, more sustainable alternatives.

Categories of New Molecules

1 Biopesticides and Biofungicides

Biopesticides are natural crop protection agents derived from living organisms or plant

sources, offering an environmentally friendly alternative to synthetic agrochemicals. They are typically target-specific, biodegradable, and safe for non-target organisms, making them ideal for sustainable agriculture. Among the most widely used are microbial metabolites, such as the insecticidal toxins produced by *Bacillus thuringiensis* (Bt) and avermectins derived from *Streptomyces* species, which are effective against mites and nematodes. Plant-based compounds also play a vital role in natural pest suppression; notable examples include azadirachtin from neem (*Azadirachta indica*), which acts as an insect growth regulator, and pyrethrins extracted from chrysanthemum flowers, known for their broad-spectrum insecticidal activity. Essential oils such as clove and eucalyptus also exhibit antifungal and repellent properties. Additionally, fungal antagonists like *Trichoderma* spp. are increasingly used as biofungicides due to their ability to produce antifungal metabolites such as gliotoxin and peptaibols, while also enhancing root growth and inducing systemic resistance in plants. Overall, biopesticides and biofungicides not only suppress pests and pathogens effectively but also contribute to plant health and soil quality, making them integral components of integrated pest management (IPM) and organic farming systems.

2 RNA Interference (RNAi)-Based Molecules

RNA interference (RNAi) is a cutting-edge gene-silencing technology that utilizes double-stranded RNA (dsRNA) molecules to suppress the expression of specific genes in pests or pathogens. When applied to crop protection, RNAi works by targeting essential genes that are critical for the survival, reproduction, or pathogenicity of the target organism. The dsRNA molecules are either expressed in transgenic plants or delivered externally through topical sprays. Upon ingestion or absorption by the pest or pathogen, the dsRNA triggers a cellular response that degrades the corresponding messenger RNA (mRNA), effectively silencing the gene and disrupting vital physiological functions. One of the key advantages of RNAi-based molecules is their high specificity. Unlike conventional broad-spectrum pesticides, RNAi targets only the intended organism without harming beneficial insects, pollinators, or other non-target species. This precision significantly reduces the ecological impact of pest management interventions. Additionally, RNAi technology presents a lower risk of resistance development, as new dsRNA sequences can be rapidly designed to target evolving pest populations or multiple genes simultaneously. A prominent example of this technology is the development of SmartStax Pro maize, which incorporates dsRNA targeting *Diabrotica virgifera* (Western corn rootworm), a

major pest of maize in North America. This transgenic maize provides effective rootworm control while reducing the reliance on chemical insecticides. Another promising advancement is the ongoing development of sprayable RNAi-based insecticides, which do not require genetic modification of the crop. These topical formulations allow for broader adoption and regulatory flexibility.

3 Nanoparticle-Based Formulations

Nanotechnology offers controlled release and enhanced efficacy of agrochemicals, making it a vital tool in sustainable crop management. Nano-formulations utilize ultra-small particles to improve the stability, solubility, and bioavailability of active ingredients, enabling more precise targeting and prolonged activity in the field. Nano-copper and nano-silver particles have shown high efficacy against a wide range of fungal and bacterial pathogens due to their strong antimicrobial properties. These nanomaterials disrupt microbial membranes and interfere with enzymatic functions, reducing pathogen viability. Nano-fertilizers, on the other hand, enhance nutrient uptake efficiency by ensuring slow and sustained release of nutrients, thereby minimizing leaching losses and reducing the frequency of application.

In addition, the encapsulation of bioactive molecules within nanocarriers such as polymeric nanoparticles or liposomes improves their environmental stability and shelf life. This encapsulation also ensures targeted delivery, minimizing exposure to non-target organisms and decreasing overall chemical usage.

4 Synergistic Molecules and Bioenhancers

Synergistic molecules and bioenhancers are compounds that improve the efficacy, uptake, and persistence of biocontrol agents or agrochemicals when used in combination. These substances do not directly control pests or diseases but act by enhancing the performance of active ingredients or stimulating plant defense mechanisms.

Chitosan, a naturally occurring biopolymer derived from chitin, is widely used as a bioenhancer due to its ability to induce systemic resistance in plants. It stimulates the production of pathogenesis-related proteins and enhances microbial colonization in the rhizosphere, thereby improving plant immunity and growth. Silicon-based molecules, when applied to crops, contribute to mechanical strengthening of cell walls, enhancing resistance against pests, pathogens, and abiotic stresses such as drought. These molecules also improve plant water-use efficiency and nutrient uptake.

Saponins, naturally occurring surfactants found in many plant species, are known to increase the permeability of cell membranes. When used alongside pesticides or fungicides, saponins enhance the penetration and absorption of active compounds, thereby boosting their efficacy even at lower doses.

Incorporating these synergistic molecules into crop protection strategies allows for reduced reliance on high-dose chemical applications, promotes compatibility with biological agents, and supports the overall goal of sustainable and integrated crop management.

5 Plant Immune Activators and Defense Primers

Plant immune activators and defense primers are molecules that enhance a plant's innate ability to defend itself against pathogens and pests. Rather than acting directly on the invading organism, these compounds stimulate or "prime" the plant's defense mechanisms, enabling a quicker and stronger response upon pathogen attack.

Salicylic acid and its synthetic analogs, such as benzothiadiazole (BTH), are well-known inducers of systemic acquired resistance (SAR). SAR leads to the activation of a wide array of pathogenesis-related (PR) genes and provides long-lasting resistance against a broad spectrum of pathogens. Jasmonic acid and its derivatives play a crucial role in inducing systemic resistance (ISR), particularly against necrotrophic pathogens and herbivorous insects. Unlike SAR, ISR is typically associated with beneficial microbial interactions, such as colonization by plant growth-promoting rhizobacteria (PGPR). Oligosaccharins, which are fragments derived from plant cell walls, function as elicitors that trigger immune signaling pathways. These molecules act as danger signals (DAMPs—damage-associated molecular patterns), alerting the plant to potential threats and initiating defense cascades.

The use of immune activators and defense primers supports environmentally sustainable crop protection by reducing dependence on chemical pesticides and enhancing plant resilience. They are compatible with integrated pest management (IPM) practices and can be used across a wide range of crops to improve disease resistance in a natural and eco-friendly manner.

Application Strategies in Field Conditions

To maximize the effectiveness of new-generation crop protection molecules, their application must be strategically integrated into existing agricultural practices. Several delivery methods have been optimized based on the nature of the molecule, crop requirements, and target pest/pathogen profile.

1 Seed treatment is commonly used for nano-formulated biofungicides and biostimulants. This approach enables early-stage protection against soil-borne pathogens and supports healthy seedling establishment.

2 Foliar application is ideal for molecules like RNAi sprays, plant immune activators, and synergistic bioenhancers. This method ensures rapid uptake through leaves, leading to timely activation of defense pathways or direct pest inhibition.

3 Soil amendments involving chitosan or bioformulations of beneficial microbes can improve rhizosphere health and plant vigor. These agents often promote induced systemic resistance (ISR) and facilitate nutrient mobilization.

4 Drip irrigation systems serve as an efficient route for delivering slow-release nano-fertilizers and biopesticides. Controlled dosing through irrigation lines minimizes runoff, reduces input costs, and ensures uniform distribution across the root zone.

Field trials have consistently demonstrated that such integrated application strategies enhance crop yield, reduce incidence of pest and disease outbreaks, and promote beneficial soil microbial communities. These methods offer scalable, sustainable solutions for modern agricultural systems.

Challenges and Regulatory Considerations

1 Regulatory complexity: Approval for RNAi, nanomaterials, and GMOs involves stringent, evolving guidelines.

2 Public perception: Concerns over biosafety and lack of awareness hinder adoption of RNAi and nanotech-based solutions.

3 High cost and scalability: Production, formulation, and delivery technologies remain expensive for large-scale use.

4 Environmental impact: Uncertainties remain about the long-term effects on non-target organisms and ecosystems.

5 Intellectual property: Patents and proprietary technologies may restrict access and increase costs for smallholder farmers.

Future Prospects

Advances in omics technologies, synthetic biology, and machine learning will accelerate the discovery of novel bioactive molecules. Combining genomics of pests and pathogens with precision delivery systems will enhance the specificity and sustainability of crop protection tools.

Collaborations between academia, industry, and policymakers are essential for scaling up and mainstreaming these innovations.

Conclusion

The shift towards sustainable agriculture necessitates the adoption of novel, environmentally sound molecules that can effectively manage pests, diseases, and abiotic stresses. New molecules such as RNAi-based agents, nano-formulations, biopesticides, and immune-priming compounds represent the future of crop protection. Their integration into holistic crop management systems will reduce dependence on synthetic chemicals, improve crop resilience, and protect ecosystems.

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MEDICINAL PLANTS IN AQUAFEED: NATURAL IMMUNOSTIMULANTS AGAINST DISEASE

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Abstract

The intensification of aquaculture, while addressing the global protein demand, has led to increased susceptibility of cultured species to stress, pathogens, and disease outbreaks. Conventional disease management strategies, particularly the use of antibiotics, have raised concerns regarding drug resistance, environmental contamination, and consumer health. As an alternative, the integration of medicinal plants into aquafeeds has emerged as a sustainable, eco-friendly, and effective approach to enhance fish immunity and overall performance. Rich in bioactive compounds such as alkaloids, flavonoids, terpenoids, and essential oils, these plants serve as natural immunostimulants that can bolster innate and adaptive immune responses. This article explores the immunomodulatory potential of key medicinal plants, their mechanisms of action, evidence from empirical studies, benefits and limitations, and the path forward for their commercial application in aquaculture.

1. Introduction

Aquaculture now contributes over 50% of the world's fish for human consumption. However, the growing reliance on high-density fish farming has escalated disease risks, often controlled using antibiotics and chemical treatments. These practices have led to drug resistance in pathogens, accumulation of harmful residues in aquatic environments, and growing consumer concerns over food safety. In this context, **phytotherapy**—the use of medicinal plants—has

gained traction as an innovative, cost-effective, and sustainable method of disease prevention in aquaculture. Drawing from traditional medicine, many plants possess antimicrobial, antioxidant, anti-inflammatory, and immunostimulatory properties that make them ideal for functional feed formulations.

This article aims to consolidate knowledge on **medicinal plants used in aquafeeds**, emphasizing their **immunostimulant effects**, **mode of action**, **species-specific applications**, and **future prospects**.

2. Key Medicinal Plants and Their Immunological Roles

The use of medicinal plants as dietary immunostimulants in aquaculture is grounded in their rich reservoir of biologically active compounds such as alkaloids, flavonoids, saponins, essential oils, terpenoids, and polyphenols. These bioactives interact with various components of the fish immune system, enhancing both innate and adaptive immunity. Among the most studied plants, **garlic (***Allium sativum***)** stands out due to its potent immunostimulatory effects attributed to sulfur-containing compounds like allicin and alliin. Inclusion of garlic powder in the diets of Nile tilapia significantly increased phagocytic activity, serum lysozyme levels, and resistance against *Aeromonas hydrophila* (Metwally, 2009). Similar effects have been observed in common carp, catfish, and rainbow trout, suggesting that garlic stimulates the non-specific immune response across species.

Turmeric (*Curcuma longa***)**, a traditional medicinal spice, contains the active compound **curcumin**, known for its strong antioxidant and anti-inflammatory properties. Curcumin modulates immune responses by upregulating antioxidant enzymes such as superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), while downregulating inflammatory cytokines like IL-1β and TNF-α. In studies with common carp and tilapia, dietary supplementation with turmeric improved growth, enhanced resistance to *Aeromonas* and *Streptococcus* infections, and promoted better oxidative balance under stress conditions (Dotta et al., 2022; Abdel-Tawwab et al., 2018).

Neem (*Azadirachta indica***)**, widely known for its antimicrobial properties, has also shown immunostimulant potential in fish. Rich in azadirachtin, nimbin, and other limonoids, neem leaf extract enhances humoral immunity, including antibody production and complement system activation. In *Labeo rohita* and catla, neem-based diets were associated with higher survival rates under *Edwardsiella tarda* challenge and better control of opportunistic bacterial

pathogens (Nayak et al., 2020). Moreover, neem possesses antifungal and antiviral actions, making it a multi-purpose additive in aquafeed.

Holy basil (*Ocimum sanctum***)**, another adaptogenic herb used in Ayurveda, is recognized for its bioactive compound **eugenol**, which enhances both stress tolerance and immune responsiveness. In rohu (*Labeo rohita*), supplementation with basil extract improved respiratory burst activity, increased lymphocyte count, and reduced cortisol levels during confinement stress, indicating both immunomodulatory and anti-stress effects (Senthil Kumaran et al., 2021). Similarly, holy basil has shown promising results in controlling *Aeromonas* and *Vibrio* infections in freshwater fish.

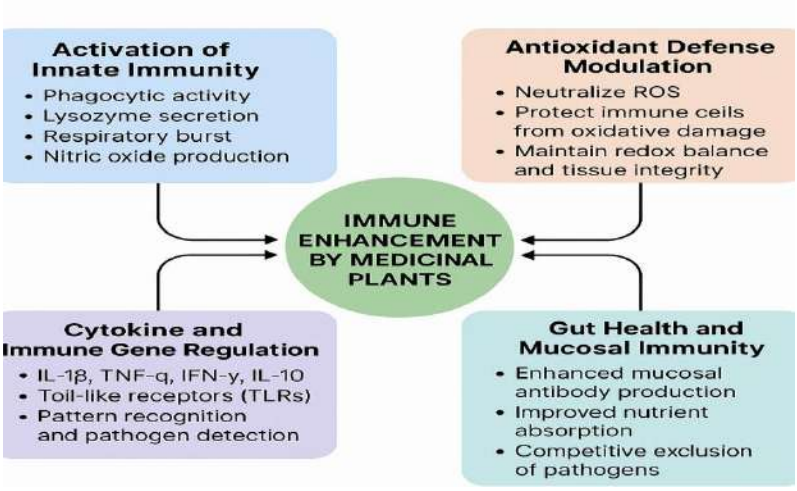
Moringa (*Moringa oleifera***)** is gaining popularity in aquaculture due to its dual role as a protein-rich feed supplement and immunostimulant. Moringa leaves contain high levels of vitamins A and C, flavonoids, and antioxidants that enhance macrophage activity and innate immune markers like lysozyme and peroxidase. In trials with tilapia and Pangasius, moringa leaf powder inclusion led to increased disease resistance, improved feed conversion, and better overall survival under bacterial challenge (Askarian et al., 2015; Aderolu & Omoya, 2020). Its affordability and abundance in tropical regions make it especially useful for small-scale, sustainable aquaculture operations.

Aloe vera (*Aloe barbadensis*)—a plant well known for its wound-healing and anti-inflammatory properties—has demonstrated effectiveness as a dietary immunostimulant in fish. Aloe contains polysaccharides such as **acemannan** that enhance leukocyte proliferation and immunoglobulin production. Studies in catfish and common carp have shown improved immune gene expression, higher serum lysozyme activity, and increased resistance to *Flavobacterium columnare* and *Aeromonas hydrophila* after aloe inclusion in diets (Abbas et al., 2017; Harikrishnan et al., 2011). Additionally, aloe vera promotes gut health by improving mucosal thickness and villi morphology, thereby aiding nutrient absorption and barrier immunity.

Together, these medicinal plants illustrate a broad spectrum of immunological benefits, acting via antioxidant protection, modulation of cytokines, enhancement of innate defense mechanisms, and support for gut-associated immunity. Their integration into functional feeds represents a promising pathway to achieving sustainable and antibiotic-free aquaculture.

3. Mechanisms of Immune Enhancement by Medicinal Plants

Medicinal plants exert their immunostimulatory effects in fish through a range of molecular and physiological pathways that enhance both innate and adaptive immunity. Primarily, their bioactive constituents such as flavonoids, alkaloids, saponins, polysaccharides, essential oils, and polyphenols modulate the immune system by stimulating the production and activity of immune cells including macrophages, neutrophils, and lymphocytes. One key mechanism is the activation of **pattern recognition receptors (PRRs)** such as toll-like receptors (TLRs), which recognize plant-derived molecules and initiate intracellular signaling cascades, leading to the upregulation of pro-inflammatory cytokines (e.g., IL-1β, TNF-α, IFN-γ) and antimicrobial peptides. These immune effectors enhance the fish's ability to neutralize pathogens during early infection stages. Additionally, medicinal plants often **boost antioxidant defense systems**, mitigating oxidative stress that commonly suppresses immunity. By upregulating enzymes like superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPx), they protect immune cells from oxidative damage and improve their functionality. Furthermore, certain compounds such as polysaccharides in **aloe vera** or **β-glucans from plant gums** enhance **phagocytic activity and respiratory burst** in leukocytes, improving the clearance of invading bacteria. Another mechanism involves modulation of the **gut-associated lymphoid tissue (GALT)**, where plant extracts improve intestinal morphology, increase mucin secretion, and support the balance of beneficial microbiota—all of which contribute to mucosal immunity. These multi-targeted effects make medicinal plants an ideal strategy for holistic immune enhancement in aquaculture.



4. Research Evidence Across Fish Species

Fish Species	Medicinal Plant Used	Observed Effects	Pathogen Challenged	Reference
Nile tilapia (*O. niloticus*)	Garlic (*Allium sativum*)	↑ Lysozyme, ↑ Phagocytosis, ↑ Survival rate	A. hydrophila	Metwally (2009)
Nile tilapia	Turmeric (*Curcuma longa*)	↑ SOD, CAT, GPx activity, ↓ IL-1β, ↑ Growth rate	S. agalactiae	Abdel-Tawwab et al. (2018)
Rohu (*Labeo rohita*)	Holy basil (*Ocimum sanctum*)	↑ Respiratory burst, ↓ Cortisol, ↑ Lymphocytes	A. hydrophila	Kumaran et al. (2021)
Striped catfish	Neem (*Azadirachta indica*)	↑ Phagocytosis, ↓ Bacterial load, ↑ Hematocrit	E. tarda	Nayak et al. (2020)

5. Practical Applications and Benefits

- ✓ **Eco-friendly and residue-free**
- ✓ **Readily available in tropical countries**
- ✓ **No resistance development**
- ✓ **Low cost for small-scale farmers**
- ✓ **Consumer-friendly—supports "organic aquaculture" labels**

Formulations: Available as powders, aqueous or ethanolic extracts, pellets, or encapsulated forms.

Feeding methods

- ✓ Mixed into daily feed
- ✓ Coated with binders
- ✓ Used during periods of stress (transport, vaccination, environmental shifts)

6. Challenges and Limitations

Despite the promising immunostimulatory potential of medicinal plants in aquafeed, several challenges and limitations hinder their consistent application in commercial aquaculture. One primary constraint is the **variability in bioactive compound concentration** due to differences in plant species, geographic origin, harvest time, and post-harvest processing methods. This inconsistency often leads to unpredictable efficacy and dose-response outcomes across trials. Moreover, some phytochemicals may exhibit **toxicity at higher concentrations**, causing adverse effects on fish growth, feed intake, or organ histology, especially in long-term usage. The **palatability of feed** can also be compromised when bitter or pungent plant materials are included at higher doses, resulting in reduced feed consumption and nutrient assimilation. Another challenge is the **lack of standardized extraction, preservation, and delivery systems** for plant-derived bioactives. Many herbal extracts degrade rapidly when exposed to heat, light, or oxygen during feed processing (e.g., pelleting or extrusion), thereby reducing their functional value. Furthermore, the **limited understanding of pharmacokinetics and metabolism** of plant compounds in fish species complicates dose optimization and withdrawal periods for use in food-grade aquaculture. Regulatory gaps also exist, as most countries lack well-defined legal frameworks or safety guidelines for the use of ethnobotanicals in fish feed, which restricts their approval and market expansion. Finally, **economic feasibility and scalability** remain a concern, particularly for small-scale farmers who may lack access to quality-controlled herbal ingredients or the technical knowledge to incorporate them effectively. Addressing these constraints requires interdisciplinary research, validation of delivery systems (e.g., microencapsulation), and harmonized global standards to realize the full potential of phytogenic feed additives in sustainable aquaculture.

7. Research Gaps and Future Directions

Standardization and Quality Control: Development of standardized herbal feed additives with consistent active content.

Mechanistic Studies: More molecular-level understanding of immune pathways.

Species-Specific Trials: Testing on lesser-known or economically important species (e.g., murrel, seabass).

Delivery Systems: Use of encapsulation, nanoemulsions, and slow-release pellets.

Economic Evaluation: Cost–benefit analysis in comparison to antibiotics and synthetic additives.

Conclusion

The use of medicinal plants as natural immunostimulants in aquaculture presents a promising, sustainable alternative to synthetic chemicals. Their diverse bioactive compounds offer multi-pronged benefits: boosting immunity, reducing stress, improving disease resistance, and enhancing growth performance. With further research, standardization, and integration into feed technologies, these plant-based additives could play a central role in the future of **eco-conscious aquaculture**.

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SUPER FOODS

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Introduction

From ancient times to the present day, food has been fundamental to human survival and development primarily serving to satisfy hunger and provide energy. In more recent years, however, food has begun to play a broader role in supporting health and wellness. Scientific evidence increasingly supports the idea that consuming fruits high in phytochemicals can help prevent chronic diseases, due to their strong antioxidant and anti-cancer characteristics.The term **"superfoods"** refers to certain foods either in their natural state or minimally processed that are exceptionally rich in nutrients and offer unique health benefits. Studies have shown that these foods may boost energy levels and strengthen the immune system, thereby improving overall well-being. Their health-promoting effects are largely due to the presence of important bioactive substances, such as omega-3 and omega-6 fatty acids, essential vitamins and minerals, probiotics, antioxidants, amino acids, polysaccharides, and various enzymes.

It's important to recognize that "superfood" is not a scientific or medical classification but rather a marketing term. It is commonly applied to agricultural products that contain unusually high amounts of beneficial nutrients or biologically active compounds that contribute to both physical and mental health. While their rise in popularity is largely driven by claims about these health benefits, it is also necessary to consider superfoods from an environmental and sustainability perspective factors that are often overlooked in mainstream discussions.

The potential health benefits linked to superfoods are mainly credited to the phytochemicals and nutraceuticals found in plant-based foods. These compounds are particularly abundant in fruits and are responsible for the high levels of antioxidants, fiber, vitamins, and minerals that earn certain foods the "super" label (Chang et al., 2018).

Common Types of Superfoods and Their Benefits

1. Leafy Green Vegetables

Examples: Kale,spinach,Swisschard.

Benefits:

- Excellent sources of vitamins A, C, and K
- High in fiber and antioxidants
- Support eye health and reduce inflammation
- May help lower cholesterol and blood pressure

2. Berries

Examples: Blueberries,strawberries,raspberries,acai

Benefits:

- Rich in powerful antioxidants, especially anthocyanins
- Enhance memory and brain function
- Contribute to cardiovascular health
- Possess anti-inflammatory and anti-cancer properties

3. Fatty Fish

Examples: Salmon,sardines,mackerel

Benefits:

- High in heart-healthy omega-3 fatty acids
- Promote brain and heart health
- Help reduce inflammation and lower triglyceride levels
- May improve mood and help manage depression symptoms

4. Avocados

Benefits:

- A good source of monounsaturated fats that support heart health
- Provide fiber and potassium
- Assist in reducing LDL (bad cholesterol) levels

- Support healthy skin and eyesight

5. Nuts and Seeds

Examples: Walnuts,almonds,flaxseeds,chiaseeds

Benefits:

- Provide healthy fats, plant-based protein, and fiber
- May lower the risk of cardiovascular disease
- Improve brain function and support satiety
- Contain anti-inflammatory nutrients

6. Dark Chocolate *(with 70% or more cocoa)*

Benefits:

- High in antioxidants and flavonoids
- Supports heart health and circulation
- May boost cognitive performance
- Known to improve mood and well-being

7. Sweet Potatoes

Benefits:

- Rich in beta-carotene, a precursor to vitamin A
- Contain fiber and antioxidants
- Help strengthen the immune system and maintain vision
- May regulate blood sugar levels

8. Whole Grains

Examples: Oats,quinoa,brownrice

Benefits:

- Provide complex carbohydrates, B vitamins, and fiber
- Support blood sugar control
- Aid in digestion
- Contribute to long-term heart health.

Incorporating Superfoods into the Daily Diet

Adding superfoods to everyday meals can significantly enhance nutritional intake by delivering a variety of health-promoting compounds. These include antioxidants, antimicrobial agents, essential fatty acids (such as omega-3 and omega-6), dietary fiber, and important

vitamins like A, B, C, and K. In many cases, these nutrients are present in concentrations higher than those found in conventional foods. Regular inclusion of superfoods in the diet has been associated with a reduced risk of several chronic conditions, including cardiovascular disease, diabetes, obesity, metabolic syndrome, neurodegenerative disorders, and certain types of cancer. Essentially, superfoods operate similarly to functional foods by helping prevent disease due to their dense concentration of bioactive ingredients. Still, it is vital that consumers rely on well-researched, scientifically validated information when selecting superfoods. Misleading claims or unverified health benefits can result in misguided choices. Moreover, consuming superfoods in supplement form without professional guidance may lead to adverse effects such as low blood pressure, oxidative stress, or nutritional imbalance in an otherwise healthy diet.

The growing trend toward superfood consumption reflects society's increasing interest in quick, effective ways to support overall health, particularly in the face of fast-paced and stressful modern lifestyles.

Future Prospects and Opportunities in Superfoods

The booming demand for superfoods is beginning to impact the agricultural and food production sectors. As demand rises, the shift toward intensive, commercially focused farming practices may accelerate, potentially influencing everything from land use and dietary patterns to environmental factors such as greenhouse gas emissions. To manage this growth responsibly, it is essential to pursue sustainable intensification of agriculture ensuring that food security can be achieved alongside efforts to mitigate climate change and preserve ecosystems.

Emerging Trends and Their Implications

1. Personalized Nutrition

- **Trend:** Growing interest in diets tailored to an individual's genetic profile, gut microbiome, and lifestyle habits.
- **Impact:** Development of custom superfood products or supplements aimed at targeted goals like immunity, cognitive support, or anti-aging.

2. Sustainable and Ethical Sourcing

- **Trend:** Consumers are placing more emphasis on sustainability, fair trade, and ethical production.
- **Impact:** Increased demand for low-impact superfoods like seaweed, and preference for products sourced through regenerative agriculture and transparent supply chains.

3. Functional Foods and Beverages

- **Trend:** A rise in consumer demand for food and drinks that provide health-specific benefits.
- **Impact:** Superfoods are increasingly used in products designed to support sleep, mental clarity, stress relief, and gut health such as turmeric shots, mushroom-based coffee, and adaptogen-infused beverages.

4. New and Rediscovered Superfoods

- **Trend:** Lesser-known or traditional foods are entering mainstream markets.
- **Opportunities Include:**
  - *Moringa* – nutrient-rich, with high levels of iron and antioxidants
  - *Seaweed* – iodine-rich and environmentally sustainable
  - *Tiger nuts* – a source of prebiotic fiber
  - *Sacha Inchi* – a plant-based omega-3 alternative
  - *Fonio & Teff* – ancient grains with excellent nutritional profiles

5. Technological Innovation

- **Trend:** Advancements in AI, biotechnology, and food science are influencing nutrition.
- **Impact:** Creation of enhanced superfoods through precision agriculture or gene editing (e.g., CRISPR-engineered berries with increased antioxidant content).

Opportunities for Growth and Product Innovation

1. Convenient Superfood-Based Products

- **Idea:** Ready-to-consume items like smoothie kits, snack bars, and protein powders featuring verified superfoods.
- **Market Opportunity:** Appeals to busy consumers seeking both health and convenience.

2. Mental Health and Cognitive Support

- **Trend:** Increased interest in natural nootropics and adaptogens, such as lion's mane, maca, and ashwagandha.
- **Business Potential:** Development of superfood-based products that help manage stress, boost mood, and improve focus.

3. Skincare and Beauty Products

- **Trend:** Integration of superfoods in topical and ingestible beauty products.

- **Examples:** Turmeric, matcha, and acai are being used for their skin-supportive properties.
- **Opportunity:** Launch of hybrid wellness-beauty products.

4. Gut Health and Fermentation

- **Trend:** Growing focus on the microbiome and digestive wellness.
- **Examples:** Fermented superfoods like kimchi, miso, and kefir are gaining popularity.
- **Opportunity:** Expanding lines of fermented functional foods and beverages.

Conclusion

The popularity of superfoods is expected to continue rising as more research confirms their health-promoting potential. Future studies should place greater emphasis on human clinical trials to provide more definitive evidence of their benefits. Additionally, the creation of an official definition for "superfoods" by regulatory authorities could help standardize product claims and improve consumer understanding, ensuring informed choices in both health and sustainability.

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BLACK SOLDIER FLY LARVAE, BIOLOGY, NUTRITIONAL COMPOSITION AND THEIR USE IN AQUACULTURE

Article ID: AG-V05-I08-84

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Abstract

The Black Soldier Fly (BSF, *Hermetia illucens*) has emerged as a sustainable and high-potential resource for modern aquaculture, offering a dual benefit of waste bioconversion and alternative protein production. BSF larvae are rich in essential amino acids, lipids, and minerals, making them an effective replacement for conventional fishmeal in aquafeeds. Their ability to thrive on diverse organic waste streams contributes to a circular bioeconomy by converting waste into valuable biomass. Cultivation systems for BSF are relatively simple, scalable, and eco-friendly, with minimal land and water requirements. Nutritional studies show that BSF-based feeds enhance fish growth, immunity, and feed efficiency, while also reducing environmental pressure from marine resource exploitation. Despite challenges like regulatory hurdles and production scalability, BSF larvae are poised to revolutionize aquaculture nutrition. This paper explores the biology, cultivation, nutritional value, and applications of BSF larvae in aquaculture, highlighting their role in promoting sustainability, economic viability, and environmental conservation.

Introduction to Black Soldier Fly (BSF) Larvae

The Black Soldier Fly (*Hermetia illucens*) has emerged as a sustainable and innovative solution in modern aquaculture. Native to tropical and warm-temperate regions, BSF larvae are increasingly recognized for their efficiency in bioconversion of organic waste into high-protein biomass. Their larvae are particularly rich in essential amino acids, fatty acids, and minerals, making them a suitable alternative to fishmeal. As the aquaculture sector faces growing

challenges with feed sustainability, the incorporation of BSF larvae has been acknowledged as a game-changing bioresource that offers both nutritional and environmental advantages.

Biology and Life Cycle of BSF

Understanding the biological aspects of the BSF is vital for optimizing larval production. The adult fly does not feed and has a short lifespan of 5–8 days, during which mating and oviposition occur. Eggs hatch into larvae within four days, and the larvae grow rapidly over a 14–18 day period depending on temperature and substrate quality. Once mature, they enter the prepupal stage and seek dry places to pupate. This self-harvesting behaviour is advantageous for collection in commercial systems. The larval stage is the most nutritive, with protein contents ranging from 37% to 63% on a dry matter basis and lipid levels up to 35%, depending on their diet and rearing conditions.

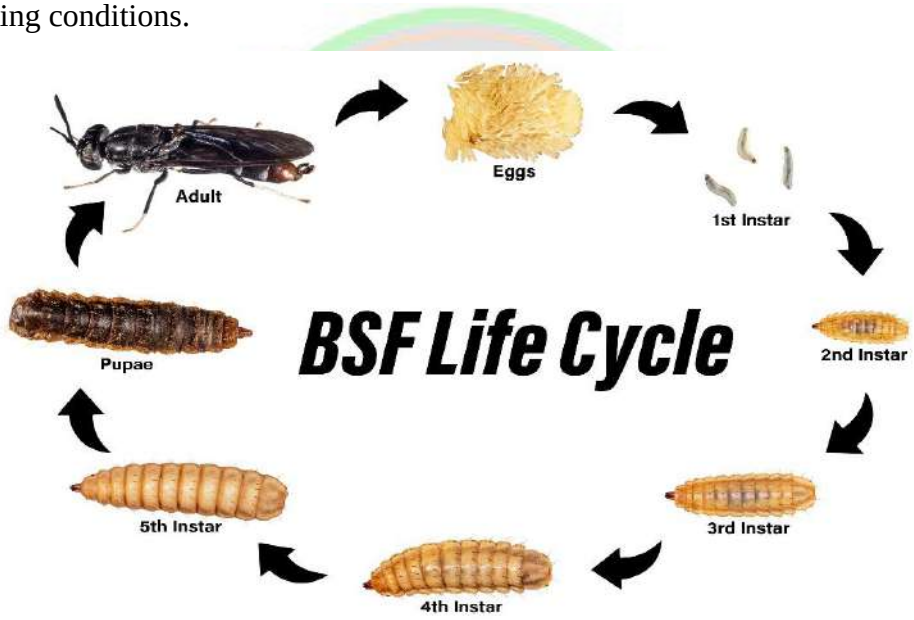

Figure 1 : Life cycle of Black soldier fly larvae

Substrate and Feed Conversion Efficiency

BSF larvae are notable for their ability to feed on a wide range of organic waste materials such as food scraps, agricultural residues, brewery waste, and manure. Their exceptional feed conversion rate (FCR) makes them a powerful tool for recycling waste into usable biomass. Studies have shown that BSF larvae can reduce organic waste mass by up to 50–70% while producing 15–25% larval biomass. They can thrive on low-value substrates without bioaccumulating heavy metals or pathogens, provided the initial feedstock is pre-screened. This contributes significantly to circular bioeconomy models, where waste management and protein production are integrated.

Cultivation Techniques and System Design

BSF larvae cultivation is relatively low-tech but requires careful control of temperature (27–32°C), humidity (60–70%), and aeration. Rearing can be done in shallow trays, or modular larvae production units depending on the scale. Automated systems have been developed for larger operations, using conveyor belts, bio-digesters, and climate control chambers. Waste is deposited in layers and mixed regularly to optimize larval growth and aeration. Self-harvesting ramps facilitate the collection of prepupae without manual interference. Hygiene protocols, including cleaning and rotation of trays, must be maintained to avoid contamination and ensure consistent output.

Figure 2 : Culture of black soldier fry larvae

Nutritional Composition and Processing

The nutritional value of BSF larvae makes them an excellent candidate for fish feed. Whole larvae or defatted BSF meal are commonly used in aquafeed formulations. The larvae contain high-quality proteins with balanced essential amino acids like lysine, methionine, and threonine, which are critical for fish growth. Lipid profiles are dominated by lauric acid, offering antimicrobial benefits. Processing methods such as drying (oven, solar, or microwave) and oil extraction influence nutrient retention and shelf life. Post-processing, the meal can be pelletized, blended with other ingredients, or used in live form for carnivorous fish species.

Nutrient	Dry larvae	Defatted larvae
Crude protein content (%)	40.88	60.69
Crude fat content (%)	20.99	7.97
Lysine (%)	1.93	2.96
Methionine (%)	0.49	0.72
Cysteine (%)	0.31	0.47
Threonine (%)	1.37	2.01
Tryptophan (%)	0.45	0.71

Source: Cullere et al. (2016)

Figure 3 : Nutritional composition of black soldier fry larvae

Applications of black soldier fly larvae in Aquaculture

The Black Soldier Fly (*Hermetia illucens*) has gained significant attention as a sustainable alternative protein source in aquaculture. Its larvae (BSFL) are rich in protein (35–55%), essential amino acids, lipids, and micronutrients, making them an effective substitute for conventional fish meal and soybean meal in aquafeeds. With the increasing demand for aquaculture products and the overexploitation of marine resources for fish meal, BSFL offers a promising solution for feed sustainability and circular bioeconomy.

BSFL can be reared on a wide range of organic waste materials, including food scraps, agricultural by-products, and manure, thereby reducing environmental pollution and contributing to waste management. After harvesting, the larvae can be processed into dried powder, oil, or whole larvae, depending on the nutritional requirements of the target fish species.

Numerous studies have demonstrated the effectiveness of BSFL-based diets in species such as tilapia, catfish, carp, and shrimp, often showing comparable or improved growth performance, immunity, and feed conversion ratios. Furthermore, BSFL contains bioactive compounds like antimicrobial peptides and lauric acid, which enhance gut health and disease resistance in aquatic species.

Despite its advantages, some challenges remain, such as standardizing mass production, overcoming consumer perception, and ensuring regulatory approvals in some regions. Nonetheless, the integration of BSFL into aquaculture represents a vital step towards sustainable

and cost-effective feed strategies, aligning with the goals of circular economy and environmental conservation.

Figure 4 : Dried black soldier larvae for aquaculture as live feed.

Environmental and Economic Benefits

The integration of BSF larvae into aquaculture offers notable ecological and economic gains. First, it reduces dependency on wild fish stocks used for fishmeal production, thus contributing to marine conservation. Second, it transforms agro-industrial waste into valuable feed inputs, reducing landfill pressure and greenhouse gas emissions. Economically, BSF farming creates local employment and income opportunities, especially in rural and peri-urban settings. The decentralization of protein production reduces feed import costs and supports localized aquafeed value chains, making it a financially viable venture for small and medium-scale aquaculture enterprises.

Regulatory Considerations and Safety

While BSF larvae are gaining acceptance globally, their regulatory status varies across regions. In the European Union, BSF larvae are authorized for use in aquafeeds under specific conditions ensuring substrate safety. In countries like the USA, Canada, and parts of Asia, the market is growing under developing regulatory frameworks. It is critical to monitor substrate quality to prevent the transmission of contaminants and pathogens. Quality assurance protocols such as Hazard Analysis and Critical Control Points (HACCP) must be implemented to standardize safety, especially for commercial-scale operations. Moreover, awareness and training among aquaculture stakeholders are essential to ensure safe adoption.

Challenges and Future Perspectives

Despite their promise, several challenges limit the widespread adoption of BSF larvae in aquaculture. These include scalability constraints, substrate availability, processing costs, and

limited awareness among farmers. Further research is needed to optimize large-scale production systems, enhance nutrient profiles via selective breeding or genetic engineering, and integrate insect farming into existing aquaculture infrastructures. Collaboration among stakeholders including research institutions, policymakers, and industry players is crucial. With growing interest in sustainable aquafeed alternatives, BSF larvae are poised to become a cornerstone of circular aquaculture models, contributing to food security and environmental sustainability.

Conclusion

The culture and application of Black Soldier Fly larvae represent a transformative innovation for sustainable aquaculture. By efficiently converting organic waste into high-quality protein and lipids, BSF larvae address two major industry concerns—feed cost and environmental impact. As the global demand for fish continues to rise, embracing such circular and eco-friendly feed sources will be imperative. With further technological refinement, supportive policy frameworks, and farmer-level adoption, BSF larvae can redefine the future of aquaculture nutrition.

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BLUE CARBON: THE MARIN'S GIFT TO NATURE

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Abstract

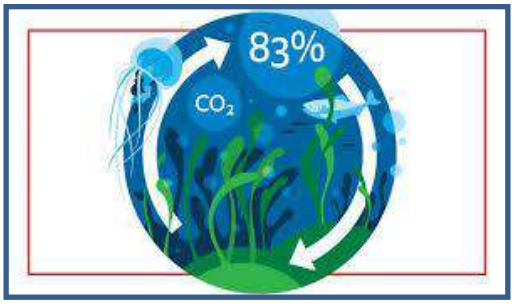
Blue carbon refers to the carbon stored in costal and marine region. These ecosystems are highly efficient carbon sinks, storing more carbon per unit area than terrestrial forests. This article highlights the role of blue carbon in mitigating climate change, the unique storage mechanisms of each ecosystem, and the threats they face from human activities and environmental change. Protecting and restoring these habitats which is essential for enhancing global carbon storage and climate resilience.

Key words

Blue carbon, mangroves, tidal marshes, seagrass meadows, kelp forests, carbon sequestration, climate change, costal ecosystem, marine conservation, carbon sink.

Introduction

Blue carbon refers to the carbon captured and stored by coastal and marine ecosystems like mangroves, salt marshes, and seagrass meadows. These ecosystems act as carbon storing unit significantly stores more carbon than terrestrial forests. The term "blue" refers to the water bodies (sea, ocean, etc.) where this carbon is stored, initially in the plant species and soils of these coastal habitats.



Different Blue Carbon Ecosystems:

A) Mangroves

Mangroves are coastal forests found in tropical and subtropical areas. The roots of these plants trap sediments, which helps prevent erosion in water bodies and promotes the accumulation of organic matter. Mangroves can store up to 3-5 times more carbon per hectare than tropical forests. They store the carbon both in the above and below the ground, which can remain in soil for long periods if the ecosystem remains intact. These forests are highly affected by deforestation due to agricultural operations, aquaculture, and urbanization of rural areas. Loss of mangroves releases the stored carbon back into the atmosphere.

B) Tidal Marshes:

Tidal marshes are wetlands found in temperate zones. They are rich in organic matter, and trap carbon from the atmosphere. These ecosystems are excellent carbon sinks, storing large amounts of carbon both in plant and in the soil. The remains of carbon in marsh sediments can be enhanced by sediment deposition during tidal flows.

C) Seagrasses:

Seagrasses are flowering plants that grow underwater in shallow coastal regions. They form extensive meadows along coastlines, providing habitat for marine life and stabilizing the seabed. They capture carbon both in their living and in the sediment beneath them. They are particularly effective at trapping fine organic matter and storing carbon in the sea. Seagrass meadows are threatened by pollution, sedimentation, and climate change. Eutrophication, caused by nutrient runoff from agriculture, can lead to algal blooms that smother seagrasses. Furthermore, heating of waters and ocean acidification put these vital ecosystems at risk.

https://wildcoast.org/bluecarboncollaborative/

Kelp

Seaweeds like kelp ("macro algae") are often left out of blue carbon discussions because accounting for the long-term fate of the carbon they store is tricky. Growing with astonishing speed up to an average of 11 inches (28 cm) per day. kelp consumes large amount of carbon dioxide. But it often grows in rocky coastal areas where the build-up of carbon rich soil is minimum. Instead, most of the carbon that kelp sequesters is exported to other places as pieces of kelp drift away to other vegetated coastal ecosystems, to nearby sediments on the deep ocean. kelp carbon can remain for thousands of years.

https://www.climate.gov/news-features/understanding-climate/understanding-blue-carbon

Importance of blue carbon

Oceans are the largest heat sink on the planet, absorbing 90% of the excess heat caused by climate change and 23% of human caused CO2 emissions. The storage capacity of Blue Carbon is 2% of the total ocean surface, but account for 50% of the ocean's carbon absorption. For example, one hectare of mangroves stores five times more carbon than a similar area of forest on land. Seagrasses are another type of coastal ecosystem critical for carbon storage.

Blue Carbon fight vs climate change

Coastal ecosystems store carbon in soils and dead natural matter such as broken twigs and dead leaves that gather on the ground in the shallows. For example, seagrass has a unique ability to prevent organic carbon from decomposing back into CO2 and carbon in seagrass is stored to six meters under the seabed in the silt on the ocean floor.

Conclusion

Blue carbon ecosystems play a vital role in combating climate change, safeguarding biodiversity, Protecting, restoring, and sustainably managing these ecosystems can boost their capacity to capture and store carbon, providing solution to global warming. To know their full potential as climate champions, urgent measures must be taken to prevent further degradation.

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CARBON TRADING IN INDIA

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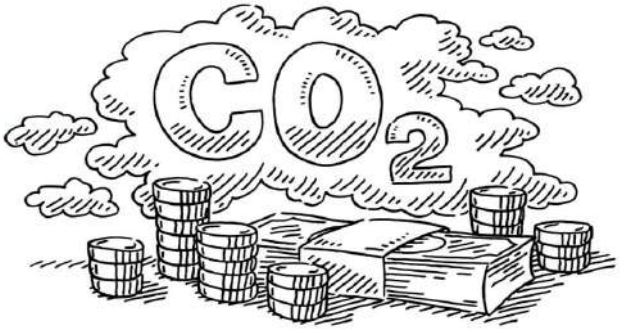
Abstract

Globally, carbon markets are emerging as key instruments to cost-effectively achieve National Determined Contributions (NDC) and organization-level Emission Reduction targets. These Market-based emission trading systems (ETS) have the potential to lower abatement costs and achieve greater emission reductions. A prospective carbon market in India could help to ensure a stable energy supply, improve its energy mix and reduce carbon emissions to achieve its 2030 goals. India is setting up a national carbon trading market and this paper aims to provide inputs regarding the prospective of carbon trading in India.

Key-words: Emission Reduction targets, emission trading systems (ETS), carbon market and carbon trading.

Introduction

India is establishing a Carbon Credit Trading Scheme (CCTS) under the Indian Carbon Market (ICM) framework to reduce greenhouse gas emissions. India's development of a carbon market is primarily driven by its commitment to global climate goals under the Paris Agreement. The scheme aims to achieve India's climate commitments, including reducing emission intensity and achieving net-zero emissions by 2070. The country aims to reduce its greenhouse gas (GHG) emissions intensity by 45% by 2030 from 2005 levels, which necessitates robust mechanisms like carbon markets.



India is moving towards a rate-based Emissions Trading System (ETS) with the adoption of the Carbon Credit Trading Scheme (CCTS) from July, 2024 and increasing alignment with global carbon markets, the country is setting the stage for a structured, rate-based Emissions Trading System (ETS). According to the World Bank's State and Trends of Carbon Pricing 2025 report, India has emerged as a notable player among emerging economies—alongside Brazil and Türkiye—in advancing carbon pricing frameworks and climate finance tools.

A Transition to Rate-Based Emissions Trading

Unlike cap-based systems where total emissions are limited, India's ETS follows a rate-based model. Here, emissions are not capped outright, but each entity is assigned a performance benchmark to limit net emissions relative to output. This model offers greater flexibility, particularly for fast-growing economies like India, by accommodating industrial expansion while maintaining climate discipline. The national ETS is set to initially cover nine energy-intensive sectors, including cement, steel and power generation. Facilities outperforming benchmark emission levels will be issued tradable Credit Certificates. The scheme thus rewards efficiency while laying the groundwork for the Indian Carbon Market (ICM).

India's Ministry of Power approved eight methodologies on March 28, 2025, for generating voluntary carbon credits. These include renewable energy, green hydrogen production, industrial energy efficiency and mangrove afforestation. This move supports the broader aim of transitioning from existing schemes such as the Perform, Achieve and Trade (PAT) programme to a market-ready, credit-based system.

Emerging Economies in Comparison

Among peer economies, China operates a similar rate-based ETS focused on the power and heavy industrial sectors. Indonesia, too, follows a rate-based structure and has recently expanded its coverage. Brazil stands apart with a cap-based system, legislated in December

2024, covering all sectors barring agriculture. India's carbon pricing framework is currently in the regulatory phase but is expected to become operational within the next fiscal year.

Voluntary Carbon Market: Expanding the Scope

India is developing a voluntary carbon market to include sectors currently outside the purview of the compliance mechanism. These encompass agriculture, afforestation and clean cooking initiatives. The objective is to channel private capital towards climate-positive projects through transparent crediting mechanisms and market participation.

The regulatory backbone for this voluntary market is provided by the Energy Conservation (Amendment) Act, 2022. This law empowers the central government to issue carbon credit certificates, thereby legitimising both compliance and voluntary credit markets.

Policy Support and Institutional Framework

Several flagship initiatives are helping to fortify India's carbon market architecture. Among them is the National Green Hydrogen Mission, which aims to produce 5 million metric tonnes of green hydrogen annually by 2030. The mission is closely tied to the carbon credit mechanism through approved methodologies that recognise hydrogen's potential as a low-emission fuel.

Meanwhile, the PAT scheme—implemented by the Bureau of Energy Efficiency (BEE) since 2012—has achieved a 15–25% reduction in emissions intensity in targeted sectors. It will gradually integrate with the ETS, ensuring a seamless policy transition.India's renewable energy ambitions remain central to its climate policy. The government aims to install 500 GW of non-fossil fuel-based power capacity by 2030, with carbon pricing acting as a complementary instrument to accelerate this shift.

Market Readiness and Governance

To strengthen governance, the National Steering Committee for the Indian Carbon Market (NSCICM) has been constituted. It includes representatives from key ministries, state governments and industry stakeholders. The Committee is responsible for setting targets, issuing guidelines and ensuring transparency in market operations. It also oversees the development of international trading mechanisms and verifies emission intensity reductions.

The Bureau of Energy Efficiency, functioning under the Ministry of Power, plays a pivotal role as the technical arm of India's climate governance. Since its inception in 2002, BEE has deployed a combination of regulatory and market-based tools to drive energy efficiency

across sectors such as industry, buildings, transport and agriculture.

Enabling Behavioural Shifts

India's approach also includes behavioural interventions. Launched as a global movement at COP27, Mission LiFE (Lifestyle for Environment) encourages individuals to adopt climate-friendly daily habits. The mission aims to mobilise one billion people by 2028 and transform 80% of Indian villages and urban bodies into green communities.

India is the first country to include LiFE in its Nationally Determined Contributions: "India will put forward and propagate a healthy and sustainable way of living based on its traditions and the values of conservation and moderation, including through a mass movement for LiFE, as a key to combating climate change."

LiFE builds upon India's environment-friendly culture and traditional practices. The average carbon footprint per person in India is 1.8 tonnes per year, as compared to the global average of 4.5 tonnes.

Green Credit Programme (GCP), which was notified in October 2023 under the Environment Protection Act, 1986. GCP promotes tree plantation on degraded forest land, issuing digital credits to participants, ranging from individuals to corporations, who maintain the plantations over a decade. The scheme is designed to expand India's green cover and incentivise voluntary environmental stewardship.

Towards a Carbon-Conscious Economy

India's carbon pricing journey is firmly grounded in the principle of Common but Differentiated Responsibilities and Respective Capabilities (CBDR-RC), ensuring that climate action remains equitable and context-specific. With institutional structures now in place and policy backing strong, the country is poised to lead by example in aligning economic development with environmental sustainability.

Present Indian Carbon Market

As per the Third National Communication (TNC) submitted to the United Nations Framework Convention for Climate Change (UNFCCC) in December 2023, India has successfully continued to decouple its economic growth from Greenhouse Gas emissions, resulting in the reduction of the emission intensity of its Gross Domestic Product (GDP). The details are given below:

Period	GHG Inventory year	Reduction in Emission Intensity w.r.t. 2005 levels
2005-2010	2010	12%
2005-2014	2014	21%
2005-2016	2016	24%
2005-2019	2019	33%

To develop the carbon market, the necessary amendments were proposed in the Energy Conservation Act, 2001 (52 of 2001) in the year 2022. Thus, the regulatory framework for the Indian Carbon Market is established under the Energy Conservation Amendment Act, 2022, where clause (w) of section 14 of the EC Act empowers the Central Government, in consultation with the Bureau of Energy Efficiency (Bureau) to specify the carbon credit trading scheme. Based on the above, the Central Government has notified the Carbon Credit Trading Scheme vide notification S.O. 2825(E), dated 28th June 2023 and amendment notification S.O. 5369(E), dated 19th December 2023. The Carbon Credit Trading Scheme (CCTS) is expected to contribute to achieving India's climate goals in line with the commitments under UNFCCC and its Paris Agreement.

To facilitate the achievement of India's enhanced Nationally Determined Contributions (NDCs) targets, the Government of India intended to develop a robust framework for the Indian Carbon Market (ICM) with the objective of decarbonizing the Indian economy by pricing the Green House Gas (GHG) emission through trading of the carbon credit certificates.

The Carbon Credit Trading Scheme (CCTS) defines the two mechanisms namely,

- Compliance mechanism
- Offset mechanism.

In the compliance mechanism, the obligated entities, which are often from energy-intensive industries are legally required to meet certain GHG emission intensity targets.

Examples: obligated entities include those in sectors like aluminum, cement, iron and steel and petroleum refining. These obligated entities shall comply with the prescribed GHG emission

intensity reduction norms in each compliance cycle of CCTS. The obligated entities which reduce their GHG emission intensity below the prescribed GHG emission intensity shall be eligible for issuance of Carbon Credit Certificates. They may need to reduce their emissions, invest in carbon capture technologies or purchase carbon credits to offset their emissions if they exceed their targets.

ln the offset mechanism, the non-obligated entities, which are not mandated to participate but choose to do so, often for reasons like corporate social responsibility or investment opportunities. They can register their projects for GHG emission reduction or removal or avoidance for issuance of Carbon Credit Certificates. Some non-obligated entities like banks and investment firms may participate in carbon trading as part of their investment strategies.

The Carbon Credit Trading Scheme is expected to contribute to achieving India's climate goals in line with the commitments under UNFCCC and its Paris Agreement.

The Perform Achieve and Trade (PAT) Scheme was initiated in the year 2012 and is a market-based mechanism aimed to improve energy efficiency in energy-intensive industries by notifying specific energy consumption reduction targets to industries (called Designated Consumers or DCs). The Government of India has developed a detailed transition plan to smoothly shift energy-intensive sectors and designated consumers (DCs) from the Perform, Achieve, and Trade (PAT) scheme to the compliance mechanism under Carbon Credit Trading Scheme (CCTS). This plan ensures continuity, consistency and alignment with national climate goals while avoiding duplication of targets. To initiate the transition, the Government has identified nine energy-intensive sectors for inclusion under the CCTS, namely, Aluminium, Cement, Steel, Paper, Chlor-Alkali, Fertiliser, Refinery, Petrochemical, and Textile.

Under the Carbon Credit Trading Scheme (CCTS), Bureau of Energy Efficiency has developed Detailed Procedure for Compliance Mechanism which covers comprehensive Measurement, Reporting, and Verification (MRV) framework to ensure accurate, transparent, and credible compliance. The key elements of the MRV framework include target setting, Monitoring, Reporting & Verification procedure along with issuance and Trading of Carbon Certificates. The development process of the MRV guidelines has followed a consultative approach which includes Stakeholder Consultations, Draft Circulation to the concerned stakeholders based on which the document was finalized. The finalized MRV framework was published by the Government of India in July 2024. An essential aspect of the MRV framework

is the verification process, which requires annual verification of GHG emissions data. To ensure credibility of the CCTS scheme, BEE will accredit Carbon Verification Agencies based on specific eligibility criteria. The detailed procedures containing the Accreditation Eligibility Criteria and Procedure for Accredited Carbon Verification Agency has been developed by Bureau of Energy Efficiency after extensive stakeholder consultation and published in July 2024.

Conclusion

With growing consciousness among nations to limit industrial GHG pollution together with positive industrial growth, carbon trading is likely to emerge as the most profitable business of the modern world. Carbon trading occupies the fastest growing financial market in the world economy presently. According to the World Bank review, the market for carbon trading in India is emerging strongly despite various economic and non-economic limitations and also as a developing nation, India has a large potential for GHG reduction and carbon trading business. Therefore, proper policies need to be formulated and implemented to hold GHG. In essence, a carbon market in India is not just about reducing emissions, it is about driving sustainable development, fostering economic growth and positioning India as a leader in the global transition to a low-carbon future.

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FOLIAR APPLICATION OF PLANT GROWTH REGULATORS ON PLANTS

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Abstract

Plant growth regulators are the chemical species that profoundly influence the growth and differentiation of various parts of plant. The activities of plant growth regulators depend on their concentration and environmental factors affecting their absorption and plant's physiological state. Plant growth regulators have the ability to effect cell division, cell structure, cell expansion, cell function, and mediate environmental stress even at low concentrations. Direct application to leaves has been shown to enhance resistance to biotic and abiotic stress. Products of Plant growth regulators are generally employed throughout viticulture, floriculture, agriculture and horticulture to increase crop yield in different environmental conditions. This article aimed to study the brief introduction and foliar applications of various plant growth regulators including auxins, gibberellins, cytokinins, ethylene, abscisic acid, brassinosteroids and jasmonates, triacontanol, triazoles and polyamines.

Keywords: Plant growth regulators, auxins, gibberellins, cytokinins, ethylene, abscisic acid.

Introduction

Foliar application of plant growth regulators can significantly impact plant growth, development and yield. These plant growth regulators (Auxins, Gibberellins, Cytokinins, Ethylene, ABA, Brassinosteroids, jasmonates, triacontanol, triazoles and polyamines), when

applied to leaves, can improve various plant characteristics such as fruit quality, yield, and seed quality. All plants naturally produce hormones in response to their surroundings that regulate their growth, development, and metabolism. Hormones are synthesized at various sites such as roots, bud and leave, and are transferred to targeted locations after binding with specific receptors [1]. Hormones control cell division, cell elongation, cell differentiation and influence plants responses to environment stress [2]. The method of application, along with environmental factors, plays a crucial role in their effectiveness.

What are Plant Growth Regulators: Plant growth regulators are organic compounds that, in small amounts, influence plant physiological processes. They are different from nutrients, although they can be used in conjunction with nutrients.

Why use Foliar Application of Plant Growth Regulators:

1. Improved nutrient uptake:

Foliar application can be a more efficient way to deliver nutrients directly to the leaves, especially in cases where soil conditions hinder root uptake.

2. Targeted delivery:

Foliar application allows for precise delivery of Plant growth regulators to specific plant parts, potentially maximizing their effect.

3. Overcoming deficiencies:

Foliar application can quickly address nutrient deficiencies that may be limiting growth or yield.

Role of Plant Growth Regulators:

1. Improved fruit quality: Plant growth regulators can influence fruit size, shape, and overall quality, potentially increasing yield and marketability.

2. Enhanced seed quality: Foliar application of Plant growth regulators can improve seed germination, vigor, and dormancy breaking, leading to better seedling establishment.

3. Altered vegetative growth: Plant growth regulators can influence plant height, stem diameter, and other vegetative characteristics, which can be desirable for specific crops.

4. Increased yield: By influencing various aspects of plant growth and development, plant growth regulators can ultimately lead to increased overall yield.

Plant growth regulators using in foliar application:

1. **Auxins:** Can promote root initiation, flowering, fruit development and apical dominance of plants
2. **Gibberellins (GA_3):** Can promote stem elongation, flowering, and fruit development.
3. **Cytokinins (BAP):** Can promote cell division and differentiation, potentially impacting leaf size and fruit development.

Preparation of Plant Growth Regulators Solution

1. Preparation of IAA solutions: To prepare 30 ppm, 60 ppm and 90 ppm of IAA solutions, 30 mg, 60 mg and 90 mg was measured by using electrical balance and taken into a glass container (100 ml) individually. The containers were mixed with 99% ethyl alcohol (10-15 ml) for dilution of IAA; and continuously stirred with glass rod for proper dilution. Then the solution was transferred into a volumetric flask (1000 ml) and make up the solution to 1 liter by adding normal water.

2. Preparation of NAA solutions: Plano fix 4.5 SL was taken as a source of Naphthalene acetic acid to prepare different doses of NAA solution. Plano fix will be containing 4.5 % of active ingredient (Alpha napthyl acetic acid). So, 1 ml of Plano fix should be dilute in 4.5 liters of water to prepare 10 ppm of NAA solution. In the similar way 60 ppm, 120 ppm and 180 ppm were prepared.

3. Preparation of GA_3 solutions: To prepare 30 ppm, 60 ppm and 90 ppm of GA_3 solutions, 30 mg, 60 mg and 90 mg was measured by using electrical balance and taken into a glass container (100 ml) individually. The containers were mixed with 99% ethyl alcohol (10-15 ml) for dilution of GA_3; and continuously stirred with glass rod for proper dilution. Then the solution was transferred into a volumetric flask (1000 ml) and make up the solution to 1 liter by adding normal water. The containers which contain solution were kept away from the light as GA_3 is photosensitive.

4. Preparation combined solutions of IAA, GA_3 and NAA: To prepare the combinations of IAA, GA3 and NAA solutions, first required quantity of IAA, GA_3 and NAA were diluted in 99 % ethyl alcohol (10-15 ml) and made up to 500 ml by adding water. Finally, this solution was mixed to make a uniform combined solution of IAA, GA_3 and NAA. The fresh solution was prepared each time of foliar application. Two foliar applications were performed only in the morning or evening hours. The uniform spraying was carried out with the help of knapsack

sprayer carefully to ensure that the leaves on both sides were completely wet with the spray solution.

Important Considerations:

1. **Method of application:** Factors such as droplet size spray volume and timing of application can affect Plant growth regulators efficacy.
2. **Environmental conditions:** Temperature, humidity, and wind can influence Plant growth regulators absorption and effectiveness.
3. **Plant species and cultivar:** Different plant species and cultivars may respond differently to Plant growth regulators.

Meteorological conditions: Environmental influences, such as time of day, temperature, humidity and wind speed influence the physical and biological aspects of foliar applications. Warm, moist and calm conditions favor highest plant tissue permeability.

1. Time of day: Ideal conditions are most likely found during the evening hours and early morning.
2. Temperature: 65-85 degrees F, 70 degrees is ideal.
3. Humidity: Greater than 70% is best.
4. Temperature + humidity: 140-160.
5. Wind speed: Less than 5 mph.

Dosage: Over-application of Plant growth regulators can lead to phytotoxicity (plant damage). In summary foliar application of Plant growth regulators is a valuable tool for improving various aspects of plant growth and yield, but careful consideration of factors like application method, environmental conditions, and dosage is crucial for maximizing their benefits.

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THERMAL EXTREMES: HEAT WAVES - IMPACTS, CRITICAL CHALLENGES AND SUSTAINABLE MITIGATION MEASURES IN THE AGRICULTURAL SECTOR

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Introduction

Climate change is a global environmental challenge. The sixth assessment report of Intergovernmental Pannel on Climate Change (IPCC) also confirmed that the climate change is real and the signatures of climate change such as rising temperature, erratic rain events etc. are felt in each and every part of globe. The major drivers of climate change include, increasing concentrations of greenhouse gases (GHGs) and atmospheric aerosols. Since, the pre-industrial era, temperature of earth is continuously rising. As per the latest report of NOAA 2024, the average surface temperature was 1.29°C more than the 20th century average and 1.46° more than the pre-industrial average (1850 to 1900). Additionally, they confirmed the occurrence of 10 warmest years in the past decade (2015-2024) and 2024 as the latest warmest year since 1850. Varying climate models projected that temperature will continue to increase by 4.0-5.8ºC in the upcoming decades.

Rapid increase in temperature will further cause changes in frequency, duration, intensity, timing, and spatial distribution of extreme temperature events. Among these, heatwaves have become more frequent and intense, posing serious threats to human health, ecological systems, agricultural productivity, and the hydrological cycle (Allan *et al.,* 2005). This article provides a comprehensive overview of heatwaves, examining their impacts, and discussing both mitigation and adaptation strategies to address the challenges in the context of a warming climate.

Heat wave

Heat wave basically refers to a condition when a temperature of an area is more than the normal temperature of that region. These heat waves generally prevail in the summer season in tropical and sub-tropical regions of the world. According to IMD, in India heat waves are more common during March to June month but it may also prevail in July in rare cases. However, the peak month of heat waves is May.

The Science Behind

Heat waves generally vary in character and its impacts also vary with time and space. It does not only be defined on the basis of high day temperature but the night time temperature also contribute to cause heat waves. If the minimum temperature or night time temperature will get increase or temperature remain high overnight then the cascading effects are felt in the next morning in the form of high day temperature than the normal conditions. Hence, warm night will also contribute to the heat wave conditions. Generally, a night is considered as warm if temperature remains ≥ 40 °C and if the minimum temperature departure from the normal is 4.5 to 6.4 °C then it is warm night and a severe warm night is when the departure from the normal temperature is ≥ 6.4 °C. The impact of heat wave gets intensified by other meteorological parameters like duration of heat waves, high humidity, high wind speed etc. The reason is that high humidity may reduces the evaporative demand and hinders the ability of human body to cool itself through sweat whereas, the high wind speed also accelerate the hot and strong winds and worsen the drought like conditions. The continuous exposure to heatwaves poses many physical and environmental stresses. So, combinedly heat wave coupled with other meteorological factors amplify the severity and consequences of heat waves on human health, ecosystems, and infrastructure.

Criteria for declaring heat wave in India

The criteria for defining the heat waves in India is provided by India Meteorological Department (IMD). Its conditions of declaration varied from region to region. The region-specific declaration criteria are explained below:

A) For plain areas

a) **Based on departure from the normal:** If the departure from the normal is 4.5 to 6.4 °C then it is called heat wave, but if the departure is > 6.4 °C then it is severe heat wave for the plain areas.

b) **Based on actual maximum temperature:** When the actual maximum temperature is ≥ 45 °C, then is refers to heat wave. On the other hand, if temperature falls ≥ 47 °C then it is severe heat wave conditions.

B) For coastal areas

a) **Based on departure from the normal:** If the departure from the normal is 4.5 °C or more then it is known as heat wave.

b) **Based on actual maximum temperature:** When the temperature remains 37 °C or more then heat wave conditions are there in coastal areas.

C) For hilly region

When the temperature is at least 30 °C or more then it is a heat-wave.

Recent Heat wave incidents in India

Since 1990, heat waves were occurred during the years: 1995, 1998, 2002, 2015, 2016, 2019, 2022 and 2024. The major heat wave prone districts are Rajasthan, Punjab, Haryana, Madhya Pradesh and Uttar Pradesh.

Impact of heat waves

Heatwaves are considered as one of dangerous natural weather hazards. Its impacts vary with the intensity and frequency of heatwave events, adaptation sources, infrastructure and preparedness in a region. The more frequent and intense heatwaves may pose serious health, environmental, social, economic and agricultural risks. Broader adverse effects of heatwaves on major agricultural sectors are described under following sub-headings:

Impacts on crop production sector

a) Crop failure:

When the temperature goes beyond the optimum level, it negatively affects the growth of plants through altering cell division, elongation rates which ultimately affect the leaf characteristics (Bita and Grates, 2013). Heat stress also induces the changes in photosynthesis and respiration. Under high temperature conditions, plant try to complete their life cycle in lesser number of days hence, shortened life cycle is experienced which further reduce the productivity of plant (Hatfield and Prueger, 2015). As stress increases, stomata's get closed which slows down or even stop diffusion of CO_2 and increase photorespiration that will inhabits the photosynthesis and other growth processes. High temperature also impairs the water uptake and cause reductions in natural cooling mechanism of plants through transpiration. Hence, the plant

undergoes some symptoms like wilt and even death which reduced the overall yield. The loss caused by heatwaves in plants depends upon many factors like its intensity, duration and the stage of the crop which undergo heat wave conditions. For most of the crops, heatwaves at reproductive stages cause more losses and among different types of plants, C3 plants get more affected by heatwaves followed by CAM and C4 plants. The recent heatwaves felt in India during 2022 caused greater loss to crops with 15% reduction in wheat yield over northern and central parts of country. In Punjab, 20% reduction in yield of green gram, 18% reduction in maize yield and 40% reduction in tomato yield (Prabhjyot-Kaur and Gosal, 2022; Sidhu, 2023). Haryana also experienced heat wave and reported with 19% reduction in chickpea and 10 to 155 reductions in wheat yield. Extreme temperature in Madhya Pradesh resulted in early maturity and lower grain weight of wheat and chickpea. Rajasthan was recorded with yield loss by about 4 to 5 q/ha and 2 to 3 q/ha in in wheat and mustard respectively (Sidhu, 2023).

b) Reduced soil moisture and water scarcity

Owing to the high temperature conditions, evaporation losses from soil get intensified which reduce the soil moisture levels and cause drought like situations and making it more difficult for crops to grow. The water demand of crops also gets increased under severe heat wave conditions due to reductions in soil moisture (Maruan *et al.*, 2025).

c) Pest infestations

Heat waves help to create ideal conditions for the growth and development of some pests. Hence, this led to more pest infestation which can cause losses to crops with great extent. For examples, the brown plant hopper in rice which comes in 1973-74 due to heat wave conditions. The life cycle of pests also gets affected with temperature.

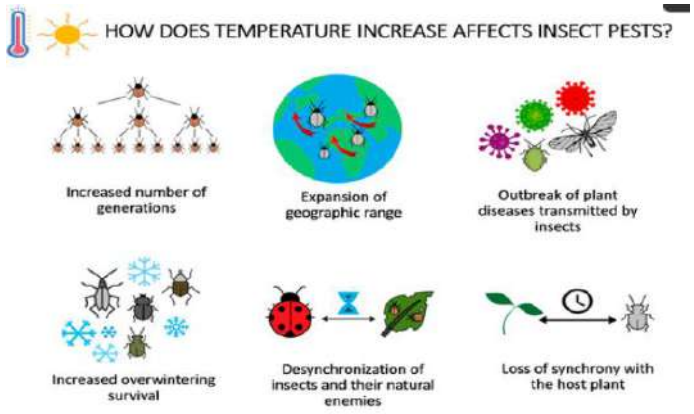

Fig. 1: Impact of heatwaves on pest (source: Skendzic *et al.*, 2021)

For example, spotted bollworm complete its lifecycle in 88 days under 16 °C temperature but the when temperature reaches 25 °C, the pest is able to complete its life cycle in 31 days which means more growth of pests. Apart from this, pests can even migrate with the changing climate (Murtaza *et al.,* 2025).

Impacts on dairy sector

Livestock play a vital role in developing the nations through its 40 % contribution to agricultural GDP. Livestock are also adversely affected by the extreme weather events. Exposure of high temperature can harm the animals and cause lower fertility rates, reduce milk production and cause death in extreme cases. In north Indian condition, when thermal heat index (THI) goes beyond 72, livestock suffer from mild heat stress, when THI reaches 80, then livestock suffer from moderate heat stress but after THI reaches 90, sever heat stress for livestock is considered (Upadhyay *et al.,* 2009). In a report prepared by Bal *et al.,* 2022, they mentioned that during the heat wave of 2022, the temperature of animals increased by 0.5 to 3.5 °C resulted in increased water need and loss of appetite and reductions in milk yield in Jammu and Kashmir. In Punjab, calf mortality and skin infections were commonly seen during heatwave of 2022. In UP, milk yield reduced by about 11%. The many other ill-effects of heat waves are described (Fig. 3) below.

Fig.2: Impact of heatwaves on livestock

(Source: https://www.pashudhanpraharee.com/impact-of-climate-change-on-livestock-2/)

Impacts on poultry sector

Heat stress interferes with the comfort level, suppresses the production capacity and growth rate of birds due to the changes in physiological, behavioral and immunological processes of birds. The rise in temperature cause broiler mortality and dropped the egg

production rates. The bird reduces its feed consumption by about 5% due to heat wave conditions in order to attain a balance between heat loss and heat gain. Egg production and quality also get affected due to the heat wave conditions. Heat wave increased the mortality rate up to 3.5-4.0% per month against the regular mortality of 0.5% per month (Bal *et al.*, 2022).

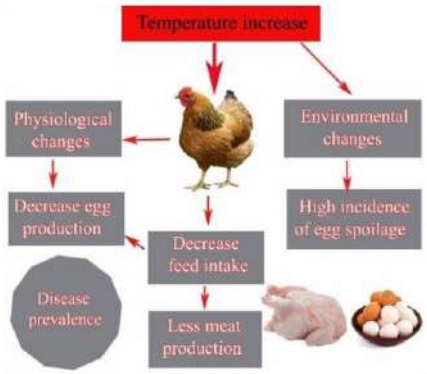

Fig. 3: Impact of heatwaves on poultry

(Source: https://www.pashudhanpraharee.com/impact-of-climate-change-on-livestock-2/)

Impact on fisheries sector

Prolonged exposure of water bodies to the sun cause warming of the water, acidification of water, lower the oxygen levels in water and impairs the quality of water and cause more diseases to the fishes. This can cause threat to the fishes and lead to fish mortality, migration and economic losses.

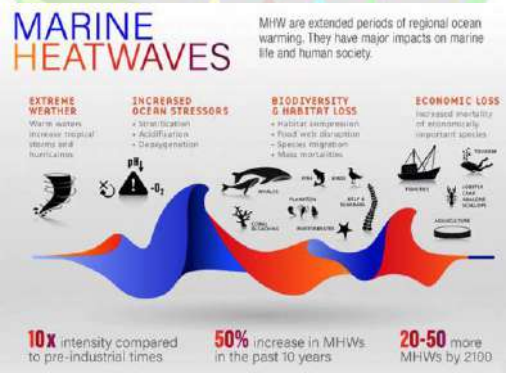

Fig. 4: Impact of heatwaves on poultry

(Source: https://www.drishtiias.com/daily-news-analysis/marine-heatwaves)

Adaptation strategies for heatwave

A) For crop production: Adjusting planting dates using climate forecasts helps avoid crop exposure to peak heat periods. Growing heat-tolerant varieties like millets and sorghum,

and diversifying crops with legumes, enhances resilience. Mulching and conservation agriculture conserve soil moisture and reduce heat stress on crops.

B) For livestock and poultry: Provide shade and shelter to animals, provide artificial cooling systems like fans for animals, and provide more water to animals, adjust the diets of animals,

C) For fisheries: Prefer shading of water bodies, use breeds that naturally adapt in heat conditions, exchange the water regularly for artificial water structures.

D) Policy and institutional support: Early warning systems alert farmers to heatwaves via mobile, SMS, and radio. Insurance, subsidies, and training enhance resilience through financial and technical support.

E) Technological and research interventions: Utilize remote sensing, climate-smart practices, and research on heat-tolerant verities/breeds, adaptation and mitigation practices to enhance resilience against heat stress.

Conclusion

Heatwaves pose a significant threat to agriculture, impacting crop yields, soil moisture, pest outbreaks, and the health of livestock, poultry, and fisheries. Elevated temperatures disrupt plant and animal functions, leading to reduced productivity and economic losses. The severity depends on the intensity, duration, and timing of heat events. Mitigating these effects requires integrated strategies, including climate-resilient technologies, adaptive management, early warnings, and infrastructure improvements to safeguard agricultural sustainability and food security.

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PEARL MILLET INBRED GERMPLASM ASSOCIATION PANEL: A USEFUL GENETIC RESOURCE TO ACCELERATE GENOMICS-ASSISTED BREEDING IN PEARL MILLET

Article ID: AG-V05-I08-89

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Abstract

Association panels represents wide genetic diversity which are useful genetic resource for mapping genes/QTLs through association studies. Pearl millet inbred germplasm association panel (PMiGAP) represents global pearl millet diversity and provides excellent resource to map genomic regions/QTLs/candidate genes regulating traits of agronomic/economic importance. The PMiGAP panel has been utilized in various studies for mapping traits related to quality, biotic and abiotic stress tolerance which have given boost to pearl millet improvement through genomics-assisted approach.

Introduction

Pearl millet (*Pennisetum glaucum* L.) is a staple crop of semi-arid and arid ecologies owing to its high tolerance to drought as well as heat. It is also the main source of fodder in marginal areas. A very low demanding crop, this millet crop ensures grain production under most hostile environments. Adaptability to environment with high temperature and drought stress, its cultivation is mainly centered in those areas where other food grain crops fail to yield. Pearl millet has a wide genetic diversity concentrated mainly in Sub-Saharan Africa and Asia. In India it is cultivated in an area of 7.36 m ha with average production of 10.67 million tons and productivity of 1449 kg/ha during 2023-24 (AICRP, Pearl millet). Owing to rich genetic diversity, researchers have utilized genetic resources for development of improved varieties/hybrids for different production environments. Approximately 56,580 accessions representative of 46 countries have been stored in 70 gene banks globally among which majority are represented by landrace collections (88%) followed by the breeding materials (6%)

developed by various research institutions. ICRISAT has the largest collection of 23092 pearl millet accessions from 52 countries (Upadhyaya et al. 2017**)**. Major contribution to genetic resources has been made by ICRISAT, Patancheru where set of pearl millet germplasm like core set (1600 accessions), minicore (238 accessions) and reference set (300 accessions) has been developed for use by researchers globally.

Germplasm association panel

A **germplasm association panel** is a carefully selected set of genetically diverse lines representing the broad variation present in a crop species. Such panels typically include landraces, breeding lines, cultivars, and sometimes wild relatives, chosen to maximize phenotypic and genetic diversity for traits of interest. Because they capture historical recombination events accumulated over many generations, association panels enable high-resolution mapping of trait–marker relationships through **genome-wide association studies (GWAS).** When paired with dense genotypic data (e.g., SNPs from resequencing) and detailed phenotyping, they provide a powerful resource for identifying candidate genes, studying allelic diversity, and developing markers for crop improvement.

Pearl millet Inbred Germplasm Association Panel

The **Pearl Millet Inbred Germplasm Association Panel (PMiGAP)** was assembled from a diverse set of germplasm, including entries from the pearl millet core collection (Bhattacharjee et al. 2007; Upadhyaya et al. 2009), landraces, cultivars, and breeding lines, representing the entire range of cultivated global diversity (Sehgal et al. 2015). Inbreeding of these open-pollinated accessions began at ICRISAT during the 2007/08 season. Each accession was planted in a single 4-m row under standard agronomic practices to ensure healthy crop growth. From each of the 250 accessions, three representative plants were selected, and one self-pollinated panicle was harvested from each. The resulting S_1 seeds were maintained on a single-plant basis, and head-to-row progenies from each accession were planted in triplets of 4-m single rows during the early post-rainy season of 2008. From one of the three representative S_1 progenies, three self-pollinated panicles were harvested to produce S_2 seed. Selection was based on slightly reduced vigour (to accelerate homozygosity), adequate selfed seed set, and typical plant architecture. This process of selfing and selection continued to advance the lines to S_3 (summer 2009), S_4 (late rainy season 2009), and S_5 (summer 2010) (Sehgal et al. 2015). This panel has been utilized by researchers globally for mapping genes/QTLs and provide a much-

needed genetic resource for accelerating genomics-assisted breeding for pearl millet improvement. Sehgal et al. (2015) reported total gene diversity of 0.54 in PMiGAP showed moderately high diversity and ensures good statistical power for carrying out GWAS and to detect rare and common alleles linked to trait of interest. The STRUCTURE analysis revealed six sub-populations which did not correspond to country of origin or agro-ecological zone. Draft genome sequence of pearl millet (Varshney et al. 2017) has been a breakthrough in pearl millet genomics where the study reported 1.79 Gb genome size with 38579 predicted genes. **Resequencing** on **994 pearl millet lines**-including wild accessions, breeding lines, and inbred PMiGAP- facilitating insights into population structure, genetic diversity, domestication, and enabling genome-enabled breeding. The resequencing data were used to establish **marker–trait associations,** define **heterotic pools,** and **predict hybrid performance**, demonstrating the crop-improvement potential of the dataset. Significant marker-trait association were found through GWAS across 288 test-cross progenies of PMiGAP lines for 20 traits.

Utilization of pearl millet association panel for mining and mapping useful traits

The vast genomic resources generated out of draft sequence provided useful information for researchers to utilize in pearl millet improvement. Sehgal et al. (2015) reported a significant association of an InDel in *LHCP* (light-harvesting chlorophyll a/b-binding proteins) gene with grain yield and yield components along with stay green traits under terminal drought stress which can be used for MAS in pearl millet for selection of high yielding stay green genotypes under terminal drought stress. Yadav et al. (2021) utilized 222 lines of PMiGAP to assess the antioxidant content of the pearl millet lines by screening for DPPH (1,1 –diphenyl-2-picrylhydrazyl) and FRAP (ferric-reducing antioxidant power) assays. Majority of the lines were found to have higher FRAP activity and DPPH scavenging activity of 58% among panel lines. DPPH showed a positive correlation with AHP and luteolin indicative of higher accumulation of phenolic compounds and antioxidant activities. DPPH radical scavenging activity ranged from 2.32-112.45% while FRAP activity ranged from 21.68-179.66 (mg ascorbic acid eq/100 g). Yadav et al. (2022) assessed global pearl millet PMiGAP lines for quality traits such as total starch, rapidly digestible starch, slowly digestible starch and resistant starch. Majority of the lines had relatively high SDS content. Ten lines were found to have high relative SDS content and low GI value. Yadav et al. (2021) did study on health metabolites by metabolomics fingerprinting of 197 pearl millet PMiGAP lines. Health benefitting metabolites were identified

which were related to dietary starch, antioxidants, vitamins and lipid metabolism related compounds. Metabolite fingerprinting was done using FIE-HRMS (Flow infusion electrospray high-resolution mass spectrometry). Sankar et al. (2021) evaluated 250 pearl millet association lines for foliar blast tolerance. Genotypes IP 11353, IP 22423 identified as ideal genotypes and IP 7910 and 7941 as desirable genotypes for tolerance to foliar blast.

Semalaiyappan et al. (2023) utilized PMiGAP lines for development of mid-density 4K SNP panel for pearl millet genomics. From whole-genome sequences of 925 lines a total of 4K SNPs were mined from which 373 pearl millet inbreds were genotyped using 4K SNPs. Rouamba et al. (2023) carried out GWAS for striga resistance and agronomic traits among 150 pearl millet genotypes of PMiGAP. The study identified substantial genetic variability and SNP markers for *Striga hermonthica* resistance and key agronomic traits in pearl millet genotypes evaluated in Burkina Faso. GWAS revealed 28 SNPs for *Striga* resistance on chromosomes 1, 2, 3, 4, 6, and 7, and markers for days to 50% flowering (chromosomes 2, 5, 6, 7), panicle length (chromosomes 2, 3, 4), and thousand-grain weight (chromosome 6). Singh et al. (2024) assessed 165 lines of PMiGAP for protein content and amino acids. Protein content varied from 10.06-20.31%. Range of amino acids varied from 0.03g/100g protein to 7.20g/100g protein. Amino acids leucine and tryptophan (essential) and glutamic acid (non-essential) were found to be the most abundant. Lines identified with highest protein content were PMiGAP 168 (20.31%), PMiGAP 311 (20.31%) and PMiGAP 167 (20.31%) along with breeding lines PMiGAP 346 (18.13%) and PMiGAP 38 (18.88%). Bhargavi et al. (2024) assessed genotypic variations in PMiGAP lines 255 for biochemical parameters influencing rancidity and their categorization using rancidity matrix.

The studied traits were comprehensive peroxide value (CPV), lipase and lipoxygenase (LOX) enzyme activities. Lines IP 5695 and IP 19334 were identified as low rancid lines based on low CAV values and other biochemical parameters under fresh and stored conditions. Singh et al. (2024) used 229 PMiGAP lines for assessing the mineral and phytate content in PMiGAP panel for Iron, zinc, calcium, magnesium, potassium, sodium and phytate. Genotypes IP-15947, IP-5121, IP-4020, IP-12768, IP-5695, IP-8786 and IP-11310 were found superior (above overall mean) for all traits studied. Seven genotypes IP-9446, IP-9301, IP-8955, IP-9406, IP-16638, IP-9282 and IP-7536 were identified that surpassed the target concentration of iron in iron-biofortified varieties. Aavula et al (2024) identified stable and high yielding genotypes out of

PMiGAP panel based on four multi-trait stability models MTSI, MGIDI, MTMPS and FAI-BLUP. Genotypes with high grain yield and early flowering were identified based on these models.

Conclusion

Pearl millet association panel provides an excellent genetic resource to speed up genomics assisted improvement in pearl millet. Identification of QTLs/genes conferring resistance to various stresses as well as enhancing quality traits will be useful to speed up variety development via deployment through marker assisted selection.

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ROLE OF UMMB AS SUPPLEMENT FEED TO RUMINANT ANIMALS

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Introduction

Urea-molasses multi nutrient (UMMB) blocks: As the name suggests, these are lick blocks containing urea, molasses, vitamins, minerals and other multinutrients. The feeding of the blocks is a convenient and inexpensive method of providing a range of nutrients required by both the rumen microbes and the animal, which may be deficient in the diet. The main justification for using the blocks depends on their convenience for packaging, storage, transport and ease of feeding. The ingredients are designed to provide a wide range of nutrients to cover all potential deficiencies. In the wet tropical regions minerals are often deficient in cut and carry grass or crop residue feeding systems. Grasses from road sides or wastelands are particularly low in minerals as generally, no fertilizer is used and the grasses have often been cut for decades for ruminant production, thus depleting the reserves of both soils and plants. Livestock raising and the consumption of animal products make a crucial contribution to the economic and nutritional wellbeing of millions of people around the world. Animal feeds play a leading role in the global food industry and feed is the largest and most important component to ensuring safe, abundant

and affordable animal proteins (IFIF, 2016). Global livestock production is constrained by the inadequate supply of feeds and forages for optimum production. At the same time land devoted for forage production does not likely to increase in the near future due to urbanization, industrialization etc. (Mahesh et al., 2014). The productivity of the livestock in most of the developing countries is much below the potential productivity.

The main constraint to livestock development in developing countries is the scarcity and fluctuation of the quality and quantity of the year-around animal feed supply. An adequate supply of livestock feed is crucial to the livelihoods of millions of people across the developing world, and not just for smallholders, but also for pastoralists and the large number of landless who depend mainly on common land for grazing (Sanford et al., 2008). Livestock production in developing countries is largely dependent on fibrous feeds mainly crop residues and low-quality pasture that are deficient in crude protein, minerals and vitamins. These roughages are unbalanced in terms of nitrogen (N), mineral and vitamin content, and they are also highly lignified. Consequently, their dry matter (DM) digestibility is reduced. These characteristics keep voluntary dry matter intake (DMI) and productivity low, and consequently the quantity of animal products (meat, milk, and draught power, wool) is limited or nil. (Bresciani, and Valdés, 2007).

Now the main feed resource for livestock in traditional production system is crop residues which is low quality high fiber content, low digestibility of roughage as a result livestock productivity will be decreased due to reduction of malnutrition with reduction of disease resistance (Malede and Takele, 2014). Earlier, the main focus was on increasing the straw utilization by ruminants. However, straw is available in large quantities but it is low in its nutritive value due to presence of high lignocellulose content, small amounts of crude protein and essential minerals. In order to find out suitable supplements for optimizing rumen fermentation so that enhanced production and reproductive performance can be achieved, another technique used was, to supplement the diet with more readily available energy and protein, which were lacking in the basal diet. The technology thus identified was use of Urea molasses mineral block lick (Mahesh et al., 2014). Addressing the nutritional problem, molasses in the form of Urea Molasses Multi-Nutrient Blocks (UMMB) were used as a livestock feed supplement in a number of countries and several studies showed positive effects on productive and reproductive performance plus an attractive benefit cost ratio for both local and crossbred dairy cows. Urea Molasses Multi-Nutrient Blocks (UMMB) are lick blocks containing urea,

molasses, vitamins, minerals and other multi-nutrients (Bohra et al.,2012). Supplementation with Urea Molasses Multi-Nutrient Blocks (UMMB) can increase digestibility of fibrous feeds by up to 20%, increase the nutrients the animal receives and can increase feed intake by 25 to 30% (yami, 2007).UMMB production and use is practiced in a number of countries and the result indicated that it improves the productive and reproductive performance of dairy cows and sheep (Aye and Adegun, 2010).Several solutions have been suggested by researchers to improve the nutritional quality and palatability of low quality roughages. In this regards, combined feeding of low-quality roughages with UMMB is considered to be one of the easiest and effective practices (Jayawickrama *et al*.,2013). Therefore, this paper aims to review and illustrate up to date information on multi-nutrient bock supplementary feeding to ruminant animals for improving productivity and to suggest the way forward.

UMMB preparation:

The preparation of UMMB has of four stages

1. Preparation of feed ingredients; as per the formula presented below.
2. Mixing the feed ingredients: Small amounts were mixed first and added to the bulk and Then thoroughly mixed.
3. Molding: Mixed materials were packed in metal container (capacity of 2 kg) and pressed with blocker for 3 minutes.
4. Drying: Blocks were dried under shed for 7 days.

UMMB Block Dimension

Formula developed and tested by Nepal Agricultural Research Council (NARC) was used to formulate the UMMB. A blocker was used which was developed by Animal Nutrition Division, NARC as described in results and discussion.

A technical specification of a UMMB block is as follows

1.Bulk density = 1.55 kg/cm3 2. Weight = 2000 g,

3.Length = 19 cm, 4. Breadth = 12 cm,

5. Height = 5.6 cm, 6. Compression = 3.54%,

7. Setting time = 3 min.

UMMB Block composition

Following ingredients were used to prepare the UMMB: (1) urea (10%), (2) molasses (> 80 0 brix) (32%), (3) rice bran (36%), (4) minerals (6%), (5) common salt (5%), (6) cement (6%)

(Water: cement is 2:5 as suggested by Bheekhee, 2010). , (7) dicalcium phosphate (5%).The keeping quality of blocks was tested and they were found safe up to 9 months if stored in cold and dry place.

Basic Feed Ingredients of the Blocks and the Characteristics of the Block Components

The urea molasses multi-nutrient block (UMMB) an excellent blend of energy, protein and minerals improved the efficiency of nutrients utilization in poor quality crop residues-based diets which constitute the bulk of DM consumed by ruminants under field conditions (Mubi etal.,2011). Formulation of multi-nutrient blocks based on low cost and locally available feed resources that do not compete with human food has been described as very promising [Makkar ,2007]. The ingredients used in the formulation of multi-nutrient blocks and their proportions determine their physico-chemical characteristics, and hence affect acceptability and intake by ruminants [Herrera et al.,2007]. Many ingredients can be used for making urea molasses blocks. The choice will depend on their availability, nutritive value, price, easy of handling and the effect on quality of block. Some of the ingredients that may be used are: Molasses, Urea, Bran (Rice, Wheat or Maize), Oilseed Meals and Cakes (Soybean, Coconut, Groundnut, Cottonseed, and Olive), Agro-industrial by-products and Miscellaneous non-conventional feeds (sugar beet pulp, Citrus pulp, tomato pulp, cassava waste, milled groundnut shells, brewers grain, bagasse, poultry manure and waste, slaughter house offal's), cement or lime, salt and, or, minerals (Herrera et al.,2007).

Thus, supplementation of UMMB lick in the ration of dairy animals helps in overcoming the malnutrition/under nutrition, increase production at farm level and generate better returns for a dairy farmer.

Advantages of UMMB feeding to animals

1. The various feed ingredients being used in the formation of UMMB are easily available in the market.
2. The method of its preparation is very easy. Farmers can make UMMB for themselves as well as can sell them in the market.
3. UMMB can be stored for a long time under dry conditions. Similarly, it can be transported to long distance without difficulty.
4. UMMB are more suitable for supplementing dry fodder-based diets for sustainability of ruminants especially during droughts and floods.

5.Licks are hard enough to control gradual intake by the animal.

6.UMMB is comparatively cheaper source of energy, protein and minerals than the conventional source of proteins like mustard or cotton oil cakes and concentrated.

Precautions before going to introduce UMMB lick to their animals

1.An UMMB cannot be used as a supplement for animals younger than 6 months, or by animals which have not eaten anything for the whole day.

2.UMMB should not have more than 10% moisture.

3.UMMB should be stored at a dry place and must be protected from rainwater so that it does not soften.

4.UMMB should be offered to the animal in the dry manger.

5.Consumption of too much UMMB must be prevented

6.Animals must always be provided with clean drinking water

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CULTURE OF MICROALGAE

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Abstract

Algae are a diverse group of photosynthetic organisms, playing crucial ecological roles in both freshwater and marine environments. **Freshwater algae**, including green algae (Chlorophyta), blue-green algae (cyanobacteria), and diatoms (Bacillariophyta), thrive in streams, rivers, and ponds, forming foundational components of aquatic food webs and contributing to primary productivity. **Marine algae** inhabit saline waters and encompass green, red (Rhodophyta), and brown algae, as well as phytoplankton, with seaweeds representing the most complex and ecologically significant macroalgae. The cultivation of algae can be achieved through **unialgal** and **axenic cultures**, each with varying levels of purity and microbial association. Successful algal culture requires optimal conditions, including suitable water quality, adequate carbon dioxide, specific mineral nutrients, appropriate light intensity, and temperature control. Algae collection techniques range from mesh netting and jar scooping to substrate and sediment sampling, while isolation methods include micropipetting, serial dilution, centrifugation, and exploiting phototactic movement. A variety of **culture media**—such as Bold's Basal Medium (BBM), Chu's media, F/2 medium, and others—support the growth of different algal groups. **Harvesting** of microalgae employs strategies like coagulation, flotation, centrifugation, sedimentation, and filtration, chosen based on scale and purpose. The comprehensive understanding and management of algal diversity, cultivation, and harvesting are pivotal for research, biotechnological applications and ecosystem health monitoring.

Introduction

Algae are photosynthetic organisms that can be unicellular or multicellular. They contain chlorophyll and, when multicellular, can form colonial or filamentous structures. Algae play a vital role in aquatic ecosystems, contributing to oxygen production and serving as a food source for various aquatic organisms.

CLASSIFICATION OF ALGAE

FRESHWATER ALGAE

- Freshwater algae thrive in various freshwater environments such as streams, rivers, and ponds. They often grow on underwater surfaces like rocks and mud. The main groups of freshwater algae include
- Green Algae (Chlorophyta): Characterized by their green color due to the dominance of chlorophyll, green algae are common in freshwater habitats and can be unicellular, colonial, or filamentous.
- Blue-Green Algae (Cyanobacteria): Though technically bacteria, cyanobacteria are photosynthetic and often grouped with algae due to their similar ecological role. They are known for their blue-green pigmentation and ability to thrive in a variety of aquatic environments.
- Diatoms (Bacillariophyta): Diatoms are a group of algae with unique silica-based cell walls. They are abundant in freshwater ecosystems and play a crucial role in the food web.

MARINE ALGAE

- Marine algae grow exclusively in saltwater environments and are vital to marine ecosystems. The most complex forms of marine algae are known as seaweeds, which are essentially large, multicellular macroalgae. There are several types of marine algae
- Green Algae: Similar to their freshwater counterparts, marine green algae contain chlorophyll and thrive in shallow coastal waters.
- Red Algae (Rhodophyta): Known for their reddish color due to phycoerythrin pigment, red algae are often found in deeper marine waters where light penetration is minimal.
- Brown Algae: Brown algae, such as kelp, are large and complex, forming underwater forests that provide habitat and food for marine life.

- Phytoplankton: These microscopic algae float in the water column and are a primary food source for many marine organisms. Phytoplankton include various groups such as diatoms and dinoflagellates.

Types of Algal Culture

Types of Algal Cultures and Their Requirements

1. Unialgal Cultures:

Unialgal cultures consist of only one type of algae, typically derived from a single clone, ensuring genetic uniformity. While the culture focuses on one algal species, it may still contain other microorganisms like bacteria, fungi, or protozoa that are naturally present or inadvertently introduced**.**

2. Axenic Cultures:

Axenic cultures are highly purified and contain only a single species of alga, free from any other microorganisms such as bacteria, fungi, or protozoa. This type of culture is crucial for research and applications where contamination could affect results or product quality.adjusted to match the natural habitat of the algae, ensuring optimal growth.

Culture Conditions

- To promote healthy growth and development, the culture conditions should closely mimic the natural environment of the algae. The following factors are essential:
- Water: A critical component, water provides the medium for nutrient uptake and waste removal. The quality of water should be suitable for the specific algae species being cultured.
- Carbon Dioxide (CO2): Carbon dioxide serves as the primary carbon source for photosynthesis. Adequate CO2 levels are necessary to support algal growth and biomass production.
- Minerals: Essential minerals, including nitrogen, phosphorus, potassium, and trace elements, are required for various metabolic processes. These nutrients must be provided in appropriate concentrations to sustain algal health.
- Light: Light is a vital energy source for photosynthesis. The intensity and duration of light exposure should be adjusted to match the natural habitat of the algae, ensuring optimal growth.

- Temperature: The temperature range for algal culture should be maintained between 15°C and 35°C, depending on the species. Maintaining the appropriate temperature is crucial for enzymatic activities and metabolic processes.

Algae Collection Methods

- Mesh Net Collection: To collect floating microalgae, use a mesh net with pore sizes between 25-30 µm. Gently scoop the net through the water, allowing it to filter out and collect the microalgae from the water's surface.
- Jar Scooping: When the water appears visibly colored due to algae, you can easily collect a sample by scooping a jar through the water. This method is simple and effective for gathering a good quantity of algae from the water column.
- Sediment Sampling: Collecting a small amount of bottom sediment can be highly effective in gathering various species of algae that inhabit or grow on these sediments. This method is particularly useful for studying benthic or sediment-associated algae.
- Hand Collection: For algae attached to substrates such as rocks, plants, or wood, manual collection is best. You can carefully pick them by hand or use a knife to gently scrape off the algae, ensuring minimal disturbance to the substrate.
- Substrate Sampling: If the algae are firmly attached, collecting pieces of the substrate itself—whether it's a rock, plant, or piece of wood—can help in gathering the attached algae. This method allows for the collection of algae in their natural attached state, preserving the ecologica6l context.

Methods for Isolation of Microalgae

1. Micropipette Method:

This method involves using a micropipette under a microscope to carefully separate individual microalgae cells from a sample. By observing the sample under the microscope, single cells can be isolated and transferred to a new medium, ensuring the collection of pure cultures.

2. Washing or Centrifugation Method:

In this technique, the water samples are repeatedly washed or subjected to centrifugation. This process helps in separating microalgae from larger organisms and debris. Centrifugation, in particular, is effective in concentrating microalgae cells by spinning the sample at high speeds, forcing the algae to settle at the bottom of the centrifuge tube.

3. Exploiting Phototactic Movement:

This method takes advantage of the natural phototactic behavior of motile microalgae, which move in response to light. By providing a light source from one direction, the motile algae will migrate towards the light. These concentrated algae can then be collected using a micropipette, effectively isolating them from the rest of the sample.

4. Serial Dilution Agar Plate Method:

This method involves preparing a series of dilution tubes from the original sample and plating them on agar plates. As the sample is diluted, a unialgal culture may emerge in one of the higher dilution tubes. This technique helps in isolating a single species of microalgae by reducing the concentration of other organisms, promoting the growth of a pure culture on the agar plate.

Culture Media for Algal Culture

Culture media, or nutrient media, are artificial or synthetic environments designed to support the growth of algae by providing essential nutrients**.**

1. Bold's Basal Medium (BBM) with Vitamins:

BBM is a freshwater algal culture medium that does not require soil extracts or additional vitamins. It is commonly used for cultivating various green algae species, such as Chlorella and Chlorococcum. This medium provides the basic nutrients necessary for algal growth, making it versatile for a range of freshwater green algal cultures.

2. Modified Chu No. 10 Medium:

This medium is widely applicable for both prokaryotic and eukaryotic algae, including blue-green algae (cyanobacteria), diatoms, and green algae. Its composition supports the growth of a diverse range of algal species by supplying essential nutrients tailored for both types of organisms.

3. Chu 13 Medium:

Chu 13 medium contains essential minerals and trace elements required for algal growth but does not include a carbon source. This makes it suitable exclusively for phototrophic algae that rely on light for their energy needs. It is particularly used for cultivating *Botryococcus braunii*, a type of green alga.

4. Miquel's Solution:

This medium is designed specifically for freshwater diatoms. It provides the necessary

nutrients to support the growth and development of these silica-rich algae, making it ideal for their cultivation.

5. F/2 Medium:

F/2 medium is one of the most commonly used enriched seawater media for cultivating marine algae, especially diatoms. It is well-suited for general marine algal culture due to its enriched composition that supports robust algal growth

6. Walne's Medium:

This medium is specifically formulated for the cultivation of marine microalgae. It provides the necessary nutrients for the growth and maintenance of various marine algal species.

7. Schreiber's Solution:

Schreiber's solution is another medium used for the culture of diatoms. It offers the essential nutrients and trace elements required for diatom growth, making it suitable for these silica-encased algae.

8. TMRL Medium:

TMRL medium is used for the cultivation of microalgae. It supports the growth of various microalgal species by providing a balanced mix of nutrients needed for their development**.**

Harvesting of Microalgae

Harvesting microalgae involves collecting the biomass while ensuring that the process does not introduce contamination or adversely affect the quality of the harvested biomass. Several methods can be employed, either individually or in combination, to efficiently harvest microalgae:

1. Coagulation and Flocculation:

This method involves the addition of coagulants or flocculants to the microalgae culture,causing the algal cells to aggregate into larger clumps or flocs. These flocs can then be easily separated from the water. This process is often used as a pre-treatment step before other harvesting methods.

2. Flotation:

Flotation involves introducing fine air bubbles into the culture, which attach to the algal cells, causing them to rise to the surface and form a concentrated algal layer. This layer can be skimmed off, allowing for efficient harvesting of the microalgae.

3. Centrifugation:

In this method, the algal culture is subjected to high-speed spinning in a centrifuge. The centrifugal force causes the denser algal cells to settle at the bottom, separating them from the liquid. Centrifugation is highly effective for concentrating microalgae but may require significant energy input.

Challenges in Microalgae Production

High production cost

Microalgae production involves significant expenses due to the need for specialized infrastructure like photobioreactors. Energy consumption is high for maintaining optimal conditions such as lighting and mixing, and the cost of supplying nutrients and carbon dioxide further adds to the overall expense.

Contamination Issues

Cultures are prone to contamination by biological agents like bacteria, fungi, and other algae, which can outcompete the desired microalgae. Environmental contaminants, such as airborne pollutants and dust, also pose risks to maintaining culture purity.

Harvesting challenges

Harvesting microalgae efficiently is difficult and energy-intensive, often involving processes like centrifugation and filtration. Achieving a high recovery rate without compromising the quality of the biomass is a common challenge.

Consistency and Scalability

Maintaining consistent growth rates and product quality across different batches is challenging. Scaling up from laboratory conditions to industrial-scale production requires overcoming various efficiency and consistency hurdles.

Environmental Factors

Microalgae are highly sensitive to changes in light intensity and temperature. Ensuring optimal environmental conditions is essential but can be difficult, particularly in regions with fluctuating climates. Additionally, large volumes of clean water are necessary, posing challenges in water-scarce areas.

Market and Economic Viability

The microalgae market faces competition from established bio-based products and synthetic alternatives. High initial investments and uncertain returns on investment due to

variable market demand make economic viability a significant concern.

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ANTIMICROBIAL RESISTANCE IN AQUACULTURE: A RISING THREAT

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Abstract

Antimicrobial resistance (AMR) has emerged as a critical challenge for global health, and aquaculture is increasingly recognized as a significant contributor. The widespread and often unregulated use of antibiotics in fish and shrimp farming to prevent disease and enhance growth has accelerated the development of resistant bacterial strains. Resistant pathogens not only threaten aquatic animal health and farm productivity but also pose risks to human health through the food chain and environmental dissemination. This article reviews the causes, consequences, and preventive strategies related to AMR in aquaculture, highlighting the urgent need for sustainable disease management practices to safeguard both aquaculture profitability and public health.

Keywords: Antimicrobial resistance, aquaculture, antibiotics, fish farming, sustainable management

Introduction

Aquaculture is the fastest-growing sector in animal food production and now provides more than 50% of global seafood consumed by humans. However, the industry faces a persistent challenge from infectious diseases, which cause severe economic losses worldwide. To mitigate these problems, antibiotics have often been used indiscriminately for both therapeutic and prophylactic purposes.

While antibiotics can temporarily control bacterial outbreaks, their misuse and overuse have led to the alarming rise of antimicrobial resistance (AMR) in aquaculture systems. Resistant bacteria can spread rapidly through pond water, sediments, and even to humans via seafood

consumption. Thus, AMR is not only an aquaculture issue but a pressing One Health concern, linking animal health, environmental health, and public health.

Understanding Antimicrobial Resistance (AMR)

Antimicrobial resistance occurs when bacteria develop the ability to survive exposure to antibiotics that would normally kill them. In aquaculture, this resistance often emerges due to several factors. The prolonged and unregulated use of antibiotics, often without proper guidance, creates strong selective pressure that favors resistant strains. Additionally, the use of sub-therapeutic doses in feed commonly practiced to promote growth or prevent disease allows bacteria to adapt gradually without being eliminated. The problem is further worsened by a lack of veterinary oversight, which leads to indiscriminate and sometimes unnecessary application of antibiotics. Moreover, aquaculture effluents contaminated with antibiotic residues and resistant bacteria enter surrounding water bodies, spreading resistance beyond farm boundaries. A major concern is that bacteria carrying resistance genes can transfer them horizontally to other bacteria through plasmids, making antimicrobial resistance even more widespread and difficult to control.

1.Causes of AMR in Aquaculture

The rise of antimicrobial resistance (AMR) in aquaculture is driven by a combination of biological, environmental, and management-related factors that favour the survival and spread of resistant bacteria.

Overuse and Misuse of Antibiotics

One of the primary contributors to AMR is the excessive and often inappropriate use of antibiotics in aquaculture. In many farms, antibiotics are administered not only for treating bacterial infections but also as growth promoters and preventive measures. This practice creates strong selective pressure, eliminating susceptible bacteria while allowing resistant strains to survive and multiply. Over time, these resistant populations become dominant within pond ecosystems, making disease outbreaks harder to control and reducing the effectiveness of available treatments.

Poor Farm Management Practices

Management practices in aquaculture also play a crucial role in driving resistance. Overcrowding, poor water quality, and inadequate biosecurity weaken the immune systems of cultured fish and shrimp, leaving them more prone to infections. In such stressful conditions, farmers often turn to antibiotics as a “quick fix” rather than addressing the root causes such as

water pollution or insufficient pond hygiene. Unfortunately, this repeated reliance on antibiotics accelerates the selection and persistence of resistant bacterial strains.

Environmental Factors

The environment serves as both a reservoir and a pathway for the spread of resistant bacteria. Wastewater discharged from aquaculture ponds often contains antibiotic residues and resistant microorganisms, which flow into nearby rivers, estuaries, and coastal waters. This not only spreads resistant bacteria to wild fish and aquatic organisms but also contaminates the broader marine environment. Once established, these resistant strains can circulate back into aquaculture systems, creating a vicious cycle of infection and resistance.

2.Impacts of AMR on Aquaculture and Public Health

Antimicrobial resistance in aquaculture does not only affect farm productivity; it also has serious implications for human health and the global seafood economy. The consequences are interconnected, making AMR a challenge that goes beyond the boundaries of aquaculture ponds.

Impact on Aquatic Animal Health

For aquatic animals, the rise of resistant bacteria translates into more frequent and severe disease outbreaks. Conditions such as vibriosis and columnaris, once treatable with antibiotics, are now harder to control because the pathogens responsible have developed resistance. As a result, shrimp and fish suffer from reduced survival rates, poor growth performance, and weakened immunity. Farmers face significant losses due to increased mortality, higher treatment costs, and reduced harvest yields, which directly impacts profitability.

Human Health Risks

The consequences of AMR in aquaculture extend to human health through multiple pathways. Resistant bacteria and antibiotic residues can enter the human body via consumption of contaminated seafood, particularly when cooking practices are inadequate. In addition, direct contact with aquaculture environments such as pond water, sediments, or infected animals poses risks for farm workers and communities living near aquaculture sites. Furthermore, environmental dissemination of resistant bacteria through wastewater and soil contamination increases the chances of resistant strains spreading into broader ecosystems. Alarmingly, some *Vibrio* species resistant to multiple antibiotics have been directly linked to foodborne illnesses in humans, highlighting the serious public health risks associated with AMR.

Economic Consequences

The economic impact of AMR in aquaculture is also substantial. International seafood trade is governed by strict antibiotic residue regulations to protect consumer health. Farmers who cannot meet these standards risk rejection of their products, loss of export opportunities, and damage to national reputations in global markets. This not only affects individual farmers but can also undermine entire regional aquaculture industries. In the long run, reliance on antibiotics and the resulting resistance can make aquaculture less sustainable and more financially risky, threatening livelihoods across farming communities.

3. Strategies for Reducing AMR in Aquaculture

Responsible Use of Antibiotics

- Only administer antibiotics under veterinary supervision.
- Avoid the use of critically important antibiotics for human medicine.
- Maintain proper dosing and treatment duration to prevent incomplete eradication of bacteria.

Biosecurity and Farm Management

- Maintain optimal water quality and reduce organic load.
- Use healthy seed certified free from major pathogens.
- Implement pond drying, liming, and disinfection between cycles.

Alternatives to Antibiotics

- **Probiotics:** Compete with harmful bacteria and enhance shrimp immunity.
- **Phytotherapy:** Herbal extracts such as garlic, neem, and turmeric show antimicrobial activity.
- **Vaccines:** Though limited in fish, vaccine development is an emerging tool.
- **Biofloc Technology:** Promotes beneficial microbes, reducing pathogen loads and minimizing the need for antibiotics.

Conclusion

Antimicrobial resistance poses a serious threat to the sustainability of aquaculture. While antibiotics have played a role in disease management, their misuse has created long-term risks for aquatic animal health, human health, and the environment. The solution lies in integrated disease management: strict biosecurity, responsible antibiotic use, and adoption of eco-friendly

alternatives. By working together farmers, scientists, policymakers, and consumers .we can protect aquaculture productivity and ensure safe seafood for future generations.

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INDIAN PENNYWORT (*CENTELLA ASIATICA*) HERBAL TEA: PHYTOCHEMICAL INTEGRITY, PROCESSING DYNAMICS, AND FUNCTIONAL BEVERAGE PROSPECTS

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Abstract

Centella asiatica (L.) Urban, commonly known as Indian pennywort, is a perennial creeping herb with a long history in Asian traditional medicine. The plant is valued for its rich phytochemical profile, including triterpenoid saponins, flavonoids, phenolic acids, and essential micronutrients. Recent interest has focused on its use as a functional beverage ingredient, particularly in herbal tea formulations. Processing methods such as fermentation and non-fermentation influence the retention of bioactive compounds and the sensory properties of the final product. Non-fermented teas typically retain higher levels of phenolic and flavonoid compounds, while fermentation can enhance aroma and taste complexity. Blending with other botanicals, such as *Zingiber officinale* (ginger) and *Camellia sinensis* (green tea), can further improve both bioactivity and consumer acceptability. This article reviews the botany, phytochemistry, health benefits, processing methods, formulation strategies, and market potential of *C. asiatica* tea, highlighting its role as a promising functional beverage.

1. Introduction

The global demand for herbal teas has expanded significantly over the last two decades, driven by consumer interest in natural health-promoting products. Unlike conventional teas derived from *Camellia sinensis*, herbal teas can be prepared from a variety of plant parts—including leaves, flowers, roots, seeds, and fruits—often consumed for their therapeutic and aromatic properties (Aoshima et al., 2007). Among these botanicals, *Centella asiatica* (L.) Urban has gained attention for its unique combination of pharmacological activities and nutritional

value. Traditionally used in Ayurveda, Chinese medicine, and various Southeast Asian healing systems, it is known for enhancing memory, promoting wound healing, reducing inflammation, and supporting overall vitality (Brinkhaus et al., 2000; Zahara et al., 2014). The incorporation of *C. asiatica* into tea formulations provides a practical delivery system for its bioactives. As a herbal infusion, it can be consumed regularly without complex preparation, aligning well with modern lifestyles. Furthermore, its mild bitterness can be balanced through careful blending with complementary ingredients such as ginger and green tea, creating a beverage that is both functional and palatable.

2. Botanical Description and Distribution

Centella asiatica is a small, perennial, stoloniferous herb belonging to the family Apiaceae. It thrives in moist, shady environments and is commonly found in marshes, paddy fields, and along riverbanks. The plant has slender creeping stems that root at the nodes, producing reniform to orbicular leaves with crenate margins. Small pinkish-white flowers are borne in simple umbels, and the fruits are laterally compressed mericarps containing a single seed (Singh et al., 2010). The species is widely distributed throughout tropical and subtropical regions, including South and Southeast Asia, Africa, Madagascar, and parts of South America (Subban et al., 2008). In India, it grows naturally in states such as Manipur, Sikkim, Assam, Kerala, and West Bengal. Its adaptability to different altitudes and climates makes it an accessible resource for smallholder farmers. Cultivation practices vary depending on the intended use. For medicinal purposes, plants are often grown in organic systems to avoid contamination with agrochemicals. Leaves are harvested throughout the growing season, as bioactive content tends to remain relatively stable under favourable environmental conditions.

3. Phytochemical Composition and Nutritional Profile

The therapeutic potential of *C. asiatica* is largely attributed to its diverse phytochemical composition. The major active constituents are triterpenoid saponins (also referred to as centellosides), including asiaticoside, madecassoside, asiatic acid, and madecassic acid (Hussin et al., 2009). These compounds have been linked to wound healing, neuroprotective effects, and anti-inflammatory activity. In addition to saponins, the plant is rich in phenolic acids (e.g., chlorogenic acid, caffeic acid) and flavonoids (e.g., quercetin, kaempferol, luteolin, catechin), which contribute to its strong antioxidant activity (Mustafa et al., 2010). The hydroxyl groups in these compounds enable them to scavenge reactive oxygen species, thereby reducing oxidative

stress and protecting cellular structures (Cao et al., 1997). Nutritionally, *C. asiatica* contains vitamins A, C, and several B-complex vitamins, along with minerals such as calcium, iron, magnesium, manganese, potassium, and zinc (Nongrum et al., 2020). Its high vitamin C content enhances collagen synthesis, complementing the wound-healing effects of asiaticoside. The bioactive profile is influenced by environmental conditions, harvesting stage, and post-harvest handling. Studies have shown that shade-grown plants may accumulate higher chlorophyll and phenolic content compared to those grown in full sun, potentially enhancing their antioxidant properties (Yusuf et al., 2013).

4. Traditional Uses and Ethnomedicinal Importance

Centella asiatica has an extensive history in traditional medicine across Asia, Africa, and the Pacific islands. In Ayurveda, it is known as *Brahmi* (though sometimes distinguished from *Bacopa monnieri*) and is considered a "medhya rasayana," or brain tonic, prescribed for enhancing memory, concentration, and cognitive longevity (Jana et al., 2010). In Traditional Chinese Medicine (TCM), it is called *Gotu Kola* or *Ji Xue Cao*, and is valued for cooling the body, detoxifying the blood, and treating skin diseases (Zahara et al., 2014). In Southeast Asian cultures, including in Indonesia, Thailand, and Malaysia, the leaves are consumed fresh as part of salads, juices, or herbal decoctions. In Sri Lanka, *C. asiatica* is a common leafy vegetable in traditional meals and is often blended into coconut-based sambols. In the Pacific islands, it is used as a medicinal infusion for treating fatigue and promoting wound healing. In the north-eastern states of India, particularly Manipur and Sikkim, fresh leaves are incorporated into salads (*singju*, *kangsu*) and chutneys. Folk healers recommend it for fevers, dysentery, liver disorders, and skin ailments. Its ethnomedicinal use as a topical application for wounds and burns is consistent with modern pharmacological evidence on its ability to stimulate collagen production (Brinkhaus et al., 2000). Such widespread traditional use, coupled with its recognized safety in long-term consumption, makes *C. asiatica* an ideal candidate for integration into functional food and beverage products such as herbal teas.

5. Health Benefits of Centella asiatica Tea

5.1 Cognitive and Neurological Effects

One of the most documented benefits of *C. asiatica* is its ability to improve cognitive performance. Animal studies and limited human trials have shown that asiaticoside and madecassoside may enhance dendritic arborization and synaptic density, supporting

neuroplasticity (Soumyanath et al., 2012). Improved cerebral blood flow has also been reported, which could help in preventing or slowing age-related cognitive decline (Dev et al., 2009). Regular consumption of *C. asiatica* tea could therefore be beneficial for students, working professionals, and elderly individuals seeking to maintain mental acuity.

5.2 Antioxidant Potential

The antioxidant properties of *C. asiatica* are largely attributed to its high phenolic and flavonoid content. These compounds neutralize free radicals, reduce lipid peroxidation, and protect DNA from oxidative damage (Zainol et al., 2003). Herbal teas made from *C. asiatica* have been shown in various studies to possess strong DPPH radical scavenging activity, often comparable to that of green tea. This suggests potential benefits in reducing oxidative stress–related conditions such as cardiovascular disease, diabetes, and certain cancers.

5.3 Anti-inflammatory and Wound Healing

Asiaticoside has been demonstrated to stimulate fibroblast proliferation and collagen synthesis, making it effective in wound healing and scar reduction (Shukla et al., 1999). In addition, *C. asiatica* extracts exhibit anti-inflammatory effects by modulating pro-inflammatory cytokines and inhibiting cyclooxygenase activity (James & Dubery, 2011). Consuming the tea internally may complement topical applications by providing systemic anti-inflammatory benefits.

5.4 Cardiovascular and Metabolic Health

Flavonoids in *C. asiatica* may improve endothelial function by enhancing nitric oxide bioavailability, leading to vasodilation and improved blood circulation (Prakash et al., 2017). Some studies also suggest modest hypoglycemic and lipid-lowering effects, which could make *C. asiatica* tea useful as part of dietary interventions for metabolic syndrome.

5.5 Adaptogenic and Stress-Relieving Effects

Adaptogens are compounds that help the body resist stress and restore physiological balance. Preliminary research suggests that *C. asiatica* may act as a mild adaptogen, improving resilience to physical and mental stressors (Gohil et al., 2010). This aligns with its traditional use as a tonic for overall vitality.

6. Processing of Centella asiatica Tea

The quality of *C. asiatica* tea depends greatly on post-harvest handling and processing methods.

The primary goal in processing is to retain bioactive compounds while achieving desirable sensory properties such as aroma, colour, and flavour.

6.1 Harvesting and Pre-Processing

Leaves are typically harvested when fully mature, as younger leaves may have lower concentrations of asiaticoside and phenolics (Hussin et al., 2009). Post-harvest, the leaves are sorted, washed, and sometimes blanched to inactivate enzymes and reduce microbial load.

6.2 Non-Fermented Tea Production

In non-fermented processing, the leaves are directly dried after cleaning. Low-temperature drying (40–60 °C) is preferred to minimize degradation of thermolabile compounds such as vitamin C and flavonoids (Zhang et al., 2013). Non-fermented *C. asiatica* teas tend to retain higher phenolic and flavonoid content compared to fermented ones, resulting in stronger antioxidant properties.

6.3 Fermented Tea Production

Fermentation involves withering, rolling, and enzymatic oxidation of the leaf tissues before drying. During fermentation, polyphenol oxidase catalyzes the oxidation of catechins and other phenolics, producing theaflavins and thearubigins that contribute to a richer colour and aroma (Heong et al., 2011). However, this process can lead to a partial loss of antioxidant potency. In sensory evaluations, fermented *C. asiatica* teas are often preferred for their smoother taste and reduced bitterness.

6.4 Blending with Ginger and Green Tea

Blending *C. asiatica* with ginger (*Zingiber officinale*) adds pungent, warming notes from gingerols and shogaols, while green tea (*Camellia sinensis*) provides catechins, theanine, and additional antioxidant activity (Senanayake, 2013). Such blends balance the herb's inherent bitterness and enhance both functional and sensory qualities.

7. Physicochemical and Phytochemical Properties

The physicochemical profile of *Centella asiatica* tea reflects both its botanical composition and the influence of processing. Parameters such as pH, moisture content, total soluble solids, and colour are important indicators of quality and stability. Non-fermented teas typically exhibit a slightly higher pH and lighter green hue, while fermented teas show a darker brownish-green colour due to oxidation of polyphenols during processing (Heong et al., 2011). From a phytochemical standpoint, the key quality markers include total phenolic content (TPC),

total flavonoid content (TFC), and antioxidant activity, often measured using assays such as DPPH, ABTS, or FRAP. Numerous studies report that non-fermented *C. asiatica* teas retain higher levels of TPC and TFC than fermented counterparts, since oxidation during fermentation can degrade certain phenolic compounds (Zhang et al., 2013; Saman et al., 2014). Nevertheless, fermentation does not necessarily reduce overall bioactivity in all cases. Some oxidation products, such as theaflavins, possess their own antioxidant and anti-inflammatory properties (Lin et al., 1998). Moreover, blending *C. asiatica* with green tea and ginger may enhance the synergistic effect of multiple phytochemicals, leading to higher composite antioxidant activity than individual components alone (Yashin et al., 2011). Moisture content in the final dried product is another critical factor, typically maintained below 7% to prevent microbial growth and extend shelf life. Proper packaging in moisture-proof materials further preserves bioactive stability and flavour quality during storage.

8. Sensory Characteristics and Consumer Acceptability

Sensory quality plays a decisive role in consumer adoption of herbal teas. While *C. asiatica* possesses a mild bitterness and grassy aroma, these attributes can be perceived either positively or negatively depending on cultural context and personal preference. In general, fermented *C. asiatica* teas score higher for aroma, colour, and smoothness of taste compared to non-fermented teas, which can be sharper and more astringent. Fermentation reduces grassy notes, mellows bitterness, and develops richer aroma compounds through enzymatic oxidation and Maillard reactions (Heong et al., 2011). Blending with ginger and green tea can significantly improve sensory attributes. Ginger imparts warmth and spiciness that complements *C. asiatica*'s herbaceous profile, while green tea adds vegetal and umami notes from amino acids like theanine. In consumer preference studies, blends incorporating moderate amounts of ginger and green tea were rated highest for overall acceptability, indicating that balanced flavour complexity encourages repeated consumption. Visual appeal is also important. Non-fermented teas tend to produce greenish-yellow liquor, while fermented teas yield a more amber-brown infusion. Both colours can be desirable depending on consumer expectations and marketing approach.

9. Comparison between Fermented and Non-Fermented Tea

The choice between fermented and non-fermented *C. asiatica* tea involves trade-offs between phytochemical retention and sensory enhancement. Non-fermented teas generally:

- Retain higher phenolic and flavonoid content

- Exhibit stronger antioxidant activity
- Have a fresher, more herbaceous flavour profile

However, they may also be perceived as overly bitter or grassy by some consumers.

Fermented teas, on the other hand:

- Develop richer, smoother flavour and aroma
- Reduce bitterness and astringency
- Produce a darker, more appealing liquor for certain markets

But these benefits come with a partial reduction in antioxidant potency due to phenolic oxidation. The optimal approach may involve partial fermentation or blending fermented and non-fermented leaves to achieve both functional and sensory goals.

10. Functional Beverage Potential

The growing functional beverage market offers substantial opportunities for *C. asiatica* tea. Functional beverages are defined as drinks that provide health benefits beyond basic nutrition, often by delivering bioactive compounds that support specific physiological functions (Granato et al., 2010).

Centella asiatica tea fits well into this category due to its antioxidant, neuroprotective, and adaptogenic properties. Its potential applications include:

- Cognitive health support for students and older adults
- Stress management as a mild adaptogen
- Skin health via collagen synthesis stimulation
- Metabolic support through mild hypoglycemic and lipid-lowering effects

The tea can be marketed in multiple formats, including loose-leaf, tea bags, ready-to-drink (RTD) bottled beverages, and instant granules. The combination of *C. asiatica* with other botanicals such as ginger, green tea, lemongrass, or mint can further expand market reach by catering to different taste preferences. Sustainability and origin-based marketing could also enhance its appeal. Highlighting cultivation in specific regions such as Northeast India or Southeast Asia, along with traditional preparation methods, can attract consumers interested in authenticity and traceability.

11. Limitations and Research Gaps

Despite the growing body of literature on *Centella asiatica* tea, several limitations remain that need to be addressed through future research. One major gap is the lack of large-scale

clinical trials confirming the health benefits attributed to *C. asiatica* consumption. While in vitro and animal studies have demonstrated antioxidant, neuroprotective, and wound-healing properties, translating these findings to human populations requires robust, controlled studies with standardized dosages and well-defined endpoints (James & Dubery, 2011). Another challenge lies in the variability of phytochemical content due to differences in cultivation conditions, harvest timing, and processing methods. Environmental factors such as soil type, light exposure, and rainfall can significantly influence concentrations of asiaticoside, madecassoside, and phenolic compounds (Yusuf et al., 2013). Without standardized cultivation and processing protocols, commercial products may vary in bioactive potency, making it difficult to guarantee consistent functional benefits to consumers. Post-harvest handling and storage stability also require more investigation. While proper drying and packaging can help preserve phenolics and vitamins, oxidation and degradation may still occur over time, particularly in humid climates. Studies assessing the shelf-life of both fermented and non-fermented *C. asiatica* teas under different packaging and storage conditions would be valuable. Finally, sensory optimization remains an area for further exploration. Although blending with other botanicals can improve flavour, more research is needed to understand how specific processing variables—such as partial fermentation or co-drying with aromatic herbs—affect the balance between bioactivity and palatability.

Conclusion

Centella asiatica tea represents a promising functional beverage with both traditional roots and modern scientific validation. Its rich phytochemical profile, particularly in triterpenoid saponins, phenolics, and flavonoids, underpins a wide range of health-promoting properties, including antioxidant, neuroprotective, anti-inflammatory, and wound-healing effects. Non-fermented processing methods generally preserve higher levels of bioactive compounds, while fermentation enhances flavour complexity and reduces bitterness. Blending with ginger and green tea can further improve both functional and sensory qualities, making the beverage more appealing to a wider audience. As consumer demand for natural, plant-based functional beverages continues to grow, *C. asiatica* tea offers considerable market potential. Realizing this potential will require standardized cultivation and processing methods, comprehensive human clinical studies, and innovative product development strategies. By bridging traditional

knowledge with scientific research, *C. asiatica* tea can be positioned as a culturally authentic and health-promoting beverage for global markets.

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ILLUMINA SEQUENCING AND ITS VERSATILE APPLICATIONS IN GENOMICS

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Abstract

Illumina sequencing is a leading next-generation sequencing (NGS) technology that revolutionized genomics by enabling massively parallel DNA analysis. We outline Illumina's workflow: preparing DNA libraries, generating clusters by bridge amplification, sequencing by synthesis (SBS) using reversible terminators, and downstream data analysis. The platform yields millions of short high-quality reads at relatively low cost, facilitating applications such as whole-genome and transcriptome sequencing. Major findings highlight its accuracy and throughput, but also note limitations: short read lengths and sensitivity to flow-cell loading, leading to overlapping clusters and ~1% error rates. We conclude that despite these limits, Illumina sequencing remains a versatile tool in genomics and continues to drive advances in research and diagnostics.

Keywords: Illumina sequencing; next-generation sequencing; genomics; DNA library preparation; sequencing by synthesis; data analysis

Introduction

Next-generation sequencing (NGS) has revolutionized genomic research by enabling the parallel sequencing of millions of DNA fragments. Among NGS platforms, Illumina sequencing is widely used for its high accuracy and throughput. Illumina technology relies on sequencing by synthesis (SBS) with reversible fluorescent terminators. The basic workflow comprises four main steps: (1) DNA library preparation, (2) cluster generation via bridge amplification, (3) SBS,

and (4) data analysis. In each sequencing run, genomic DNA (or cDNA) is fragmented, adapters are ligated, clonal clusters are formed on a flow cell, and the sequence of each cluster is read base-by-base. These massive parallel steps produce short reads (typically 36–300 bp each) with high accuracy. Illumina data have been applied across genomics, transcriptomics, and epigenomics, making this technology a foundation of modern genomic studies.

DNA Library Preparation

Illumina library preparation creates a pool of DNA fragments with platform-specific adapters on each end. First, genomic DNA is sheared into short fragments (typically 200–500 bp) by physical or enzymatic means. Then synthetic adapter sequences are ligated to both the 5′ and 3′ ends of each fragment, enabling later amplification and sequencing. Modern kits use "tagmentation," combining fragmentation and adapter ligation in one step for efficiency. Following adapter ligation, libraries are PCR-amplified and size-selected for the desired insert range. The result is a sequencing-ready library of millions of DNA fragments, each tagged with Illumina-compatible adapters.

Cluster Generation (Bridge Amplification)

After library preparation, the adapter-tagged DNA library is loaded onto an Illumina flow cell surface, which is coated with two types of complementary oligonucleotide primers. Single-stranded library fragments bind to these primers. During bridge amplification, each bound fragment bends over to hybridize to a nearby complementary primer, forming a bridge. DNA polymerase then amplifies the fragment in place, creating many copies (a cluster) at that location. Repeated cycles of denaturation and extension produce a clonal cluster of ~1000 identical DNA strands, all tethered to the flow-cell surface. This massively parallel amplification yields millions of spatially separated clusters across the flow cell lanes.

Sequencing by Synthesis (SBS)

Illumina's sequencing by synthesis (SBS) determines the sequence of bases in each cluster by iterative fluorescence imaging. In each cycle, the flow cell is flooded with four different nucleotide analogues (A, T, C, G), each carrying a reversible terminator and a unique fluorescent dye. A DNA polymerase and sequencing primer are present. During a cycle, one complementary nucleotide is incorporated into each cluster's DNA strand. Because the terminator blocks further extension, only one base is added per cycle. After incorporation, the flow cell is imaged with lasers: each cluster emits a fluorescence signal whose color identifies

the added base. Then a chemical reagent cleaves the terminator and the fluorescent dye, restoring the 3′-OH and allowing the next cycle. These steps repeat for ~36–300 cycles, depending on read length.

Data Analysis

Once sequencing is complete, Illumina's on-board software converts raw fluorescence images into base calls and quality scores. The primary output is typically in FASTQ format. Key data analysis steps include: (1) Demultiplexing: Assigning reads to samples by index sequences. (2) Quality control: Assess metrics like yield, Q30 scores, and cluster density. (3) Alignment: Mapping reads to a reference genome using algorithms like BWA or Bowtie. (4) Variant Calling: Identifying single nucleotide polymorphisms (SNPs), insertions/deletions, and structural variants by comparing to the reference. (5) Quantification and Annotation: Counting reads for gene expression (RNA-Seq), or analyzing methylation levels, and annotating variants.

Conclusion

Illumina sequencing has become a cornerstone of modern genomics due to its high throughput, accuracy, and versatility. By fragmenting DNA and attaching adapters, forming clonal clusters, and using reversible-terminator SBS chemistry, Illumina platforms produce billions of bases of sequence data per run. This technology underpins many genomic applications – from whole-genome and exome sequencing to transcriptome and epigenome studies – providing researchers with powerful tools to decode genetic information. Despite limitations such as short read lengths and sensitivity to sample loading, Illumina sequencing continues to be widely adopted due to its robustness and scalability.

Acknowledgement

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MULTIPLYING BAMBOO THE SMART WAY: INSIDE THE WORLD OF PLANT TISSUE CULTURE

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Abstract

Micropropagation is an advanced plant tissue culture technique that allows for the rapid, large scale production of genetically uniform and disease-free bamboo plants, making it an effective method for sustainable propagation. Traditional propagation methods, such as seed sowing, rhizome division, and culm cuttings, are limited by irregular flowering, low seed viability, and slow multiplication rates. Micropropagation overcomes these challenges by culturing small explants, such as nodal segments or shoot tips, in sterile nutrient media with plant growth regulators to induce shoot proliferation, multiplication, rooting, and acclimatization. This method ensures year round production, uniform quality, and high survival rates, while also supporting the conservation of rare and endangered bamboo species. By merging scientific precision with sustainability, micropropagation meets growing industrial, ecological, and economic demands for bamboo, offering a reliable solution for commercial plantations.

Keywords: Bamboo, Micropropagation, Tissue culture, Plant growth regulators, Explants, Sustainable production, Conservation

Introduction

In today's race for sustainable solutions, bamboo is emerging as a green hero. But did you know that scientists have found a way to grow thousands of bamboo plants from just one? Welcome to the world of micropropagation a modern technique that's helping farmers and the

planet. Micropropagation is a method of growing many new plants quickly by using small pieces of plant tissue in a clean, controlled lab environment. It involves culturing small plant parts, such as shoot tips, nodal segments, or meristem tissues, on nutrient media enriched with specific plant growth regulators to promote the development of shoots and roots. (Nath *et al*., 2015). Micropropagation overcomes the limitations of conventional propagation methods, such as low multiplication rates, seasonal dependence, and the risk of spreading diseases. It is widely used for the commercial production of ornamentals, fruit crops, forest species, and medicinal plants, as well as for conserving rare and endangered species.

The Drawbacks of Traditional Methods

Bamboo may be one of the fastest growing plants in the world, but ironically, multiplying it using traditional methods is not as easy or fast as it seems. Farmers and foresters have long relied on conventional techniques like seed propagation, rhizome division, and culm cuttings. While these methods are natural and time tested, they come with several significant limitations that slow down large scale bamboo production.

1. Rarity of Seeds

After flowering, the parent plants often die, and seeds are available only for a very short window. This makes seed based propagation unreliable and impractical for consistent commercial production.

2. Low Germination Rate

Even when seeds are available, their viability drops quickly. Bamboo seeds tend to lose their germination ability within weeks unless carefully stored under controlled conditions. This makes long term storage and transport difficult. A very short time frame in which seeds can be used effectively.

3. Slow Growth Through Vegetative Methods

Propagation through rhizomes (underground stems) or culm cuttings (stem segments) is commonly used, but it’s labour intensive and slow. Each rhizome division yields only a limited number of new plants, and these methods require mature, healthy parent plants that are often in short supply. Moreover, they take a long time to establish and grow into full plants.

4. Risk of Disease Transmission

Since vegetative methods use parts of the parent plant, any pests or diseases in the mother stock are easily passed on to the new plants.

This can lead to unhealthy plantations with stunted growth, pest problems, or poor yield especially when propagated at scale

5. Lack of Uniformity

Plants produced through traditional methods often show variation in size, growth rate, and productivity. This lack of uniformity can be a disadvantage in commercial plantations where consistent quality and yield are important for market success.

6. Limited Scalability

Perhaps the biggest limitation is the inability to scale up quickly. Large scale bamboo plantations need thousands or even millions of plants. Traditional propagation simply cannot meet this demand in time, especially for high yield commercial species.

Popular Bamboo varieties grown through micropropagation:

Several high value bamboo species are now being successfully multiplied using tissue culture techniques. One of the most widely micropropagation used in ***Dendrocalamus asper***, also known as Giant Bamboo or Sweet Bamboo, prized for its large size and edible shoots. ***Bambusa balcooa,*** commonly used in construction and paper production, is another favorite due to its thick, solid culms. (Singh *et al*., 2012). In India's northeastern states, ***Dendrocalamus hamiltonii i***s preferred for its fast growth and tender shoots. The strong and hardy ***Dendrocalamus strictus***, also called Iron Bamboo, is widely used for making incense sticks and furniture and is often propagated in dry regions. ***Melocanna baccifera***, an important bamboo species in the Northeast, is grown for its edible shoots and is propagated in labs due to poor seed availability. Other species like ***Bambusa bambos***, known for its tall, thorny structure, and ***Thyrsostachys siamensis***, popular for ornamental and export purposes, are also commonly grown through micropropagation. These varieties are chosen not only for their economic importance but also because they are difficult to multiply using traditional methods, making tissue culture the ideal solution. (Das *et al*., 2008).

From Lab to Field: How it works?

In controlled laboratory environments, scientists can turn a tiny piece of bamboo into thousands of healthy, identical plants all within a matter of months.

1. Selection: Starting with the Right Plant

Everything begins with the careful selection of a healthy parent plant, typically one known for its strong growth, disease resistance, or commercial value. A small piece of tissue

usually a shoot tip, node, or bud is cut from the parent plant. This tiny piece is called an explant. It carries the genetic makeup of the mother plant and will be used to generate all future clones. The quality of the explant determines the quality of every new plant produced. A poor quality explant can result in weak or diseased clones. (Arya *et al*., 2009).

2. Surface Sterilization: A Clean Start

The explant is then subjected to a rigorous sterilization process to remove any surface microorganisms like bacteria or fungi. Wash explants under running tap water to remove dust and debris. Treat with mild detergent (e.g., Tween-20) for 5-10 minutes. Rinse thoroughly with sterile distilled water. Surface sterilize using 70% ethanol (30-60 seconds) followed by 0.1% mercuric chloride or sodium hypochlorite for 5-10 minutes. Rinse 3-5 times with sterile distilled water to remove traces of sterilant. Sterilization is done inside a laminar airflow cabinet, which maintains a sterile, dust free environment.

3. Culture Initiation: Let the Growth Begin

Place sterilized explants vertically in Murashige and Skoog (MS) medium supplemented with cytokinin (e.g., BAP benzyl aminopurine @ 4mg/lit) to induce shoot proliferation. Maintain cultures in a growth room at 25 ± 2°C, with a 16-hour photoperiod and 60-70% relative humidity.

4. Multiplication: One Becomes Many

After initiation, the small shoots are carefully cut and transferred to fresh media supplemented with 5mg/lit BAP is used for quick shoot multiplication. This step is repeated multiple times to rapidly produce dozens, hundreds, or even thousands of identical shoots.

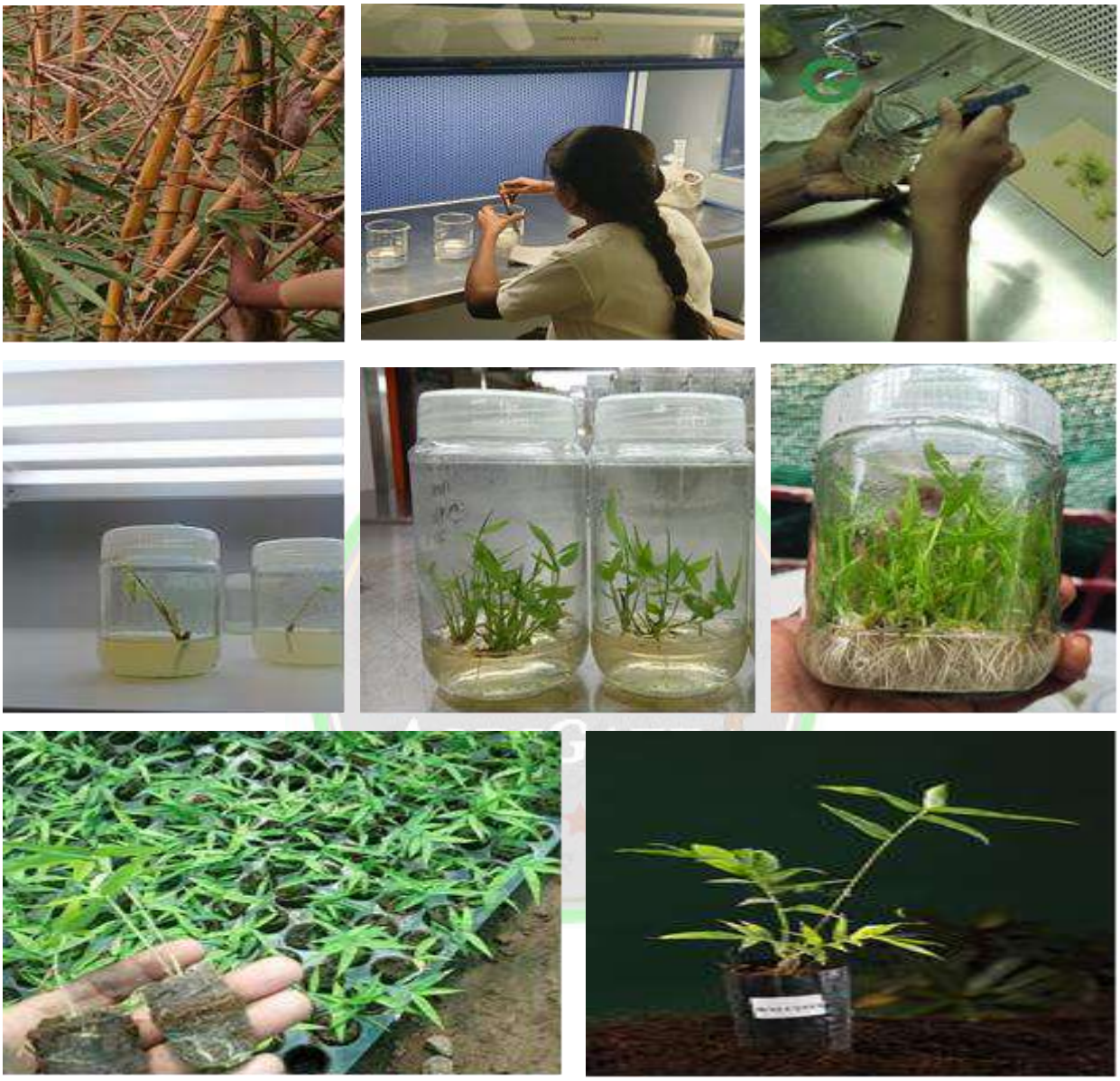
5. Rooting: Developing a Strong Foundation

The next step is to induce root formation. The shoots are transferred to a different medium, containing 0.75mg/lit indole-3-butyric acid (root stimulating hormones). In this rooting medium, the plantlets begin to develop healthy roots, preparing them for life in soil.

6. Hardening: Transitioning to the Real World

The plantlets are initially grown in sterile, humid condition and are too delicate to survive in the field without preparation. During hardening, they are first moved to shaded area with controlled humidity that is primary hardening and then slowly exposed to natural light and outdoor condition (secondary hardening). This helps to develop stronger roots, thicker shoots and resistant to stress. Proper hardening improves their survival rate and ensures healthy growth after

transplantation. With plant tissue culture, what starts as a tiny shoot can turn into thousands of uniform healthy bamboo plants all within a few months.



Science behind the shoots:

Behind the clean glass walls of a tissue culture lab, a quiet revolution is taking place one that is changing how we grow bamboo. Micropropagation, or plant tissue culture, is more than just a lab technique; (Negi *et al*., 2011) it's a powerful tool that makes plant production faster, cleaner, and more efficient.

1. Rapid Multiplication: Growing More in Less Time

Some bamboo species take years to produce usable offshoots, and seeds are rarely

available. Micropropagation overcomes this hurdle by speeding up the process in a big way.

2. Disease-Free Planting Material: Healthy from Day One

One of the hidden dangers in traditional bamboo farming is the spread of diseases through soil or infected parent plants. With micropropagation, plants are grown in completely sterile conditions, free from pests, fungi, bacteria, or viruses. Every tissue cultured plant starts its life in a clean environment and is monitored throughout the process to ensure health and hygiene.

3. Conservation of Rare and Endangered Bamboo Species

Many native bamboo species are endangered (*Ochlandra* sp., *Decaryochloa* sp., etc.,) due to habitat loss and overharvesting. Since bamboo flowers rarely and irregularly, natural regeneration is difficult. Micropropagation offers a safe and sustainable way to multiply these rare species, allowing scientists to grow them in controlled environments and reintroduce them into the wild or botanical gardens without harming wild populations.

4. Uniform Quality: Consistency You Can Count On

When you grow bamboo through tissue culture, every plant is a genetic clone of the original, meaning they all share the same growth rate, height, culm thickness, and resistance traits. This level of uniformity is especially important for commercial bamboo plantations where consistency in quality and size is essential.

5. Science Meets Sustainability

Micropropagation is not just about growing more plants its about growing smarter, cleaner, and more sustainably. Whether it's meeting industrial demands, conserving endangered species, or empowering rural farmers, the benefits of this method are far reaching. As climate change and deforestation threaten natural ecosystems, plant tissue culture is proving to be one of the most promising green technologies of our time especially when it comes to a plant as important as bamboo.

Conclusion

Bamboo has always been a symbol of strength, flexibility, and sustainability. Now, thanks to the science of micropropagation, we have a powerful tool to harness its full potential faster, cleaner, and smarter than ever before. From a single shoot, thousands of healthy, identical bamboo plants can be grown disease free, high quality. There are challenges from contamination risks to high startup costs but innovation, training, and government support are helping overcome these barriers. With growing awareness and access to technology, micropropagation is no longer

confined to research labs it's becoming a practical solution for farmers, foresters, and environmentalists alike. In the end, micropropagation is not just about growing bamboo. It's about growing opportunities, resilience, and a more sustainable future one lab grown shoot at a time.

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RESILIENCE IN EVERY ROOT: THE PROMISE AND POTENTIAL OF FOOD FORESTS FOR SUSTAINABLE AGRICULTURE IN INDIA

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Introduction

With growing technologies and depleting soil health, farming in India has quietly become one of the most expensive yet least profitable businesses. When a person hears about a "farmer", the image that comes to their mind is a man struggling to sustain his livelihood. This stereotype, which is backed up by several evidence, exists for a reason; it reflects the reality. The backbone of India's agriculture sector consists of the small and marginal farmers in the majority, who operate in less than 2 hectares of land with limited resources, erratic climatic conditions, as well as growing input costs. Despite feeding the nation, their plates remain empty of both stability and profit. The system is broken, and fixing it doesn't mean growing more; it means growing smarter, for which Food forest will be an ideal solution.

How Food Forest Work? The Core Components

Food Forest is a replicable agriculture system of a natural structure of a forest developed with a perspective with a motive of intensifying the productivity and profitability. It involves several crop varieties harvested in unison in layers like trees, shrubs, herbs, as well as root crops in a given parcel of land.

Table 1. Different Layers of a tree and their relevant fruits suited for Kerala

Layer	Fruits Suited for Kerala
Tall Trees (Canopy layer)	Mango (multiple varieties), Jackfruit (varikka, koozha), Mahua, Tamarind
Short Trees	Guava, Drumstick (Moringa), Rose Apple (Champika), Custard Apple,

(Low tree layer)	Amla
Shrubs	Pomegranate, Lemon, Curry Leaf (Kariveppila), Coffee, Clove
Herbs	Malabar Spinach (Basella), Amaranthus, Indian Sorrel (Puli Keerai), Waterleaf (Kozhuppa)
Ground Covers	Pumpkin, Sweet Potato, Cowpea (Payaru), Ash Gourd (Kumbalam)
Root Crops	Yam (Chena), Taro/Colocasia (Chembu), Tapioca (Kappa), Arrowroot
Climbers	Passion Fruit, Ivy Gourd (Kovakka), Snake Gourd (Padavalanga), Bottle Gourd (Churakka), Beans

It can be further supported with animals like chicken, ducks, or bees based on location, in order to make it a highly productive as well as self-supportive one. Table 1 lists the trees that can be utilized to start a food forest in Kerala. It shows its applicability in Indian Agro-Climatic Zones, as an indication of the importance of this specific system.

How food forest help solve many modern problems?

India's agriculture sector, since the green revolution, has been dominated by the monocropping system over several decades to a point at which it is now also known as the traditional method, which is not true. The Monocropping system, which was once considered a boon for serving food & achieving security goals, is now a major cause of soil degradation, pest and disease accumulation, and rising chemical dependency. The challenges faced by Indian farmers are exacerbated by shrinking landholdings, erratic rainfall, and escalating input costs, leaving the small and marginal farmers vulnerable to economic instability. In this situation, Food forest offer a system-based alternative. They give numerous benefits which including food, livelihoods, environmental services (habitat, heat mitigation, carbon storage), and open new hubs for recreation, education, and help in community building.

Supporting a diverse mix of crops with phased harvests, it has the potential for farm-based tourism. It reduces the reliance on any single crop. Even if a crop fails, income would be steady, as there's either another crop alternative readily available or a tourism stream to fall back on. Even if the market access is restricted, inadequate, or entirely missing, a well-maintained food forest will attract visitors and generate direct returns from the farm itself.

Many farmers are already shifting toward diversified livelihoods such as dairy, poultry, and apiculture in response to climate stress and natural resource depletion. The food forest model doesn't just support this; it integrates into a single system. It improves the resource use efficiency as food forest increase the biological diversity and interrupt pest cycles, which in turn help reduce the net chemical usage. The system requires very little water because of its scientific arrangement of layers that mimic a natural forest. By Canopy layering, the soil conserves the moisture, and this helps reduce the irrigation demand, and additionally provides a microclimate that will help in diversifying the species. There will be more natural nutrient cycling without needing more fertilizer spraying and Labour, which is a major problem in India. This model isn't just ecologically beneficial - it's economically practical. It reduces long-term input costs, ensures consistent field nutrition, and increases resilience. For smallholders facing land, capital, and climate constraints, food forest present a way out.

Maintenance

A food forest is designed to be self-sustaining, which makes maintenance easier. The natural canopy cover or the Mulch maintains the soil moisture and further prevents weed growth, and this reduces the need for irrigation or weeding Activities. The soil is kept rich with a steady supply of compost, and nitrogen-fixing plants like moringa and cowpea. Water is managed through swales and pits, which hold the rainwater and let it percolate into the ground slowly. Pruning is minimal and done seasonally. Pests rarely cross ETL due to a wide variety of biodiversity. With the trees and shrubs varieties fruiting at different times, harvesting or plucking is spaced out and not rushed. Aside from the occasional task like fixing fences or supporting a trellis, most of the work shifts from daily labour to occasional maintenance. Over time, this means less stress, less effort, and a more manageable farming routine.

Agro Tourism and How Food Forest Earns Revenue

They invite people onto the farms, not just to look at, paying a premium entry fee, tourists can hike through these jungles, harvest fruits and vegetables with one's bare hands, eat as they like right in the field, and take home baskets of just-picked, pesticide-free produce. It's less a matter of buying food than it is an experience. Unlike monoculture farms where a single crop is raised & sold in a small harvest window, food forest yield hundreds of varied plants, fruits, vegetables, & nuts over several layers & seasons. This variety provides year-round productivity of the farm as well as a richer experience of visiting. A visitor can pick a basket of guava,

spinach, turmeric, & bananas. The entrance fee covers what would otherwise have been received on the crop in the market, with the value-added of a pleasant experience. Tourists have exact knowledge of what they're eating as well as how it is being produced. Farmers have cash income in hand with good margins. It offers transparency, a pleasant experience for tourists, as well as a continuous income stream for the farmer.

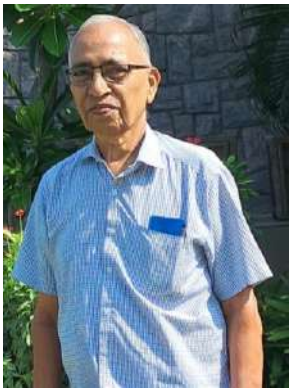
Additional Perks of a Food Forest

A food forest can still yield returns either in on-farm processing of excess into products such as pickles, oils, or dried herbs, or in Agro-tourism with a resultant premium revenue stream. Many species characteristic of these systems—a few examples include bamboo, sesbania, and moringa- provide animal fodder, fuelwood, green mulches, and organic pest repellents. It's not merely a matter of growing more; it's a matter of requiring less from elsewhere.

Food forest stratified nature develops microclimates that protect both soil and crops from unpredictable climates. Their permanent ground cover, food forest, also tend to optimize evaporation and maintain soil moisture over more extended periods. On erosion-prone land like floodplains or hillslopes, food forest prevent soil from washing away with deep-rooted trees and shrubs, reducing runoff while at the same time binding soil together and saving not just aesthetically for tourism but also preventing potential environmental threats such as landslides.

As climate uncertainties rise, food forest are living natural insurance. The diversity in food forest shows that if one crop is adversely affected, the other crop yields, even if it is affected by droughts, pests, or other stresses. This method therefore minimises the risk of crop failure by reducing the vulnerability of farmers and promoting overall stability of the agricultural system.

Case Study



Mr. Narayanan, Farmer, Kerala

Mr. Narayanan, a 73-year-old farmer in Palakkad district of Kerala, is an ideal example of a thriving food forest, who has an extremely successful food forest of 8 acres and 45 cents. It is a fertile, self-sufficient ecosystem that now accommodates over 60 diverse species of crop plants, trees, and animals. His journey began in economic hardship, with just 8 cents of land and very little capital. He initially started with basic crops like coconut and banana, focusing not on tourism, but on a real estate-integrated farming model. After growing his first successful

food forest, he sold the land, now rich with productive trees, for a good profit. Seeing the potential, he repeated this process several times until he built up enough income to create his dream food forest on the current 8.45-acre plot.

Unlike most farms, Narayanan's field is run without any chemical input. His strategy relies on high plant diversity, which reduces the spread of pests naturally. Due to labour shortages, he installed drip irrigation. He avoids weeding, believing that the natural mulch from leaf shedding after the rainy season not only nourishes the soil but also suppresses unwanted weed growth. Table 2 depicts the 7-layer food forest model with specific varieties.

Table 2. Narayanan's Food Forest: 7-Layer Model With Specific Varieties

Layer	Plants & Varieties from Narayanan's Food Forest
Tall Trees	Mango (20 varieties), Jackfruit (Plavu, 10-20 varieties), Chola Mathram Chakka - orange, red, yellow, white types, Coconut – Red & Black, Tamarind, Mahua
Short Trees	Guava (Perakka), Rose Apple (Chambakka) (5-6 types), Custard Apple (Seethappazham), Soursop (Mullatha), Mangosteen, Rambutan, Barbados Cherry, Carambola (Starfruit), Ramphalam, Maram Mundiri
Shrubs	Mulberry, Dragon Fruit, Perfume Fruits, Boloiva, Ramphal
Herbs	Agathi Cheera, Dasapushpam (Cheroola,Mukkutti, Uzhinja,(Karuuka, Nilappana, Muyal cheviyan, Vishnukaranta, Poovamkurunnila,Kayyonni) ,Turmeric, Ginger, Chamakandi , garlic
Ground Covers	Pumpkin (Kumbalam), Ash Gourd, Ivy Gourd (Kovakka), Bitter Gourd (Kaippa), Snake Gourd (Padavalanga)
Root Crops	Tapioca (Kappa), Yam (Chena), Taro/Colocasia (Chembu)
Climbers	Beans, Bottle Gourd (Churakka), Black Pepper (Kurumulaku), Banana Plants (Vazha): Poovan Vazha, Red Banana, Nendran, Pazha Kunja, Kola-type, 2 Addi Ulla Vazha, Other trunk-like banana types (Total ~20 varieties)

The mixture of cows, poultry, ducks, and recently included fish provides organic material, used as manure. These animals also help in pest control, enhancement of soil quality, as well as crop defence. Narayanan recently added a horse, not for farming purposes but with an eye towards

aesthetic and tourism value, with individuals being able to ride through the forest scenery. Despite the food forest being built up over the past 13 years, there is yet maturing of some species of trees occurring, and maximum yield is still to be realized. Nonetheless, Narayanan is not deterred; his attitude is not towards maintaining an already-completed product in the forest, but as a living, changing legacy.

Conclusion

Food forest are not a luxury or an idealistic vision for the Indian climate. They are a strategic response to the failing economics of Indian agriculture. They exhibit a long-term scientific solution that not only reduces input costs but also minimizes risks and creates year-round yields. In contrast to conventional farming, Food forest construct resilience into the land itself. For small as well as marginal farmers with unpredictable rains, degrading soils, and decreasing profits, this method provides food security, medicinal values, fodder, fuel, and marketable products - all under one canopy. Changing over to a food forest is not quick work, but it is feasible, replicable, and is based on traditional Indian ecosystem knowledge.

Indian farmers perceive agriculture as a livelihood for survival and not innovation. The hesitation in the adoption is because of their livelihood at stake, so innovative methods are considered luxury. This article reimagines farms though food forest by empowering farmers to view farming as a profit-making enterprise or business model and food forest offer.

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SHELF- LIFE IMPROVEMENT IN CUT FLOWERS

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Abstract

Enhancing the shelf life of flowers is a multi-disciplinary challenge involving horticultural science, biochemistry, and supply chain management. combination of good agricultural practices, proper post-harvest handling, and modern preservation technologies can significantly extend the vase life of flowers, benefiting producers, retailers, and consumers alike. Gerbera respond best to a mix of 2% sucrose, 0.6% vinegar, 1% CaCl2 in water-doubling vase life to ~ 16 days.

Introduction

Cut flowers are widely valued for their aesthetic appeal, fragrance, and symbolic significance. However, their post-harvest longevity, or shelf life, is limited due to physiological and biochemical changes that occur after harvest. Improving the shelf life of cut flowers is vital for enhancing market value, reducing waste, and satisfying consumer demand. Various pre-harvest, harvest, and post-harvest strategies have been developed to extend the vase life of flowers.

Factors Affecting Shelf Life

1. Pre-Harvest Factors

Genetic Makeup: Different flower species and cultivars have varying vase lives. For example, carnations and chrysanthemums generally have longer shelf lives than tulips or lilies.

Nutrient Management: Adequate fertilization, especially potassium and calcium, enhances structural integrity and reduces senescence.

Irrigation Practices: Proper water management prevents water stress, which can accelerate aging.

2. Harvest Factors

Maturity Stage: Flowers harvested at the correct developmental stage last longer. For instance, roses should be harvested at the tight bud stage, while gerberas are best cut when the outer petals are almost horizontal.

Time of Day: Harvesting during cooler parts of the day, preferably early morning, helps reduce respiration rates and wilting.

Handling Techniques: Gentle handling minimizes mechanical injuries that can lead to microbial infection.

3. Post-Harvest Factors

Temperature Control: Prompt cooling and maintenance of the cold chain (0–5°C) slows down respiration and ethylene production.

Humidity: High relative humidity (90–95%) prevents desiccation and wilting.

Ethylene Management: Ethylene-sensitive flowers (e.g., carnations, orchids) should be protected using ethylene inhibitors like silver thiosulphate (STS) or 1-Methylcyclopropene (1-MCP).

Water Quality: Use of clean, deionized water reduces microbial growth in vase solutions.

Shelf-Life Improvement Techniques

1. Use of Floral Preservatives

Floral preservatives typically contain:

Sugars (for energy)

Biocides (e.g., chlorine, 8-HQC to suppress microbes)

Acidifiers (e.g., citric acid to maintain pH)

Commercial mixtures and homemade (bleach + sugar + lemon) extend life substantially (e.g., “Flora Life” and “Chrysal”)

Gerbera respond best to a mix of 2% sucrose, 0.6% vinegar, 1% CaCl2 in water-doubling vase life to ~ 16 days.

2. Preventing Ethylene Damage

Ethylene inhibitors like 1-MCP or silver-based solutions block ethylene receptors and slow aging. Hot water treatments and chemicals (e.g., sodium azide, catechol) can delay senescence-extending vase life by ~4 days in roses.

3. Pulsing Treatment

Flowers are treated with high concentrations of sucrose and germicides for a short period (e.g., 16–24 hours) before storage or transport to maintain freshness and delays the microbial blockage.

4. Use of Growth Regulators

Cytokinin (e.g., benzyl adenine) delay senescence.

Gibberellins help in delaying leaf yellowing in some species.

5. Packaging and Transportation

Modified atmosphere packaging (MAP) and vacuum packing can extend shelf life helps maintain the freshness during transit.

Use of ethylene absorbers during shipping (e.g., potassium permanganate sachets).

6. Nanotechnology

Recent research suggests nano-silver and zinc oxide solutions can improve water uptake and reduce microbial growth in vase solutions.

Chrysanthemum: up to 23 days vs.~4 days in control.

Carnations and roses: benefits observed with AgNPs, humic acid, aloe gel.

Recent Research and Innovations

Genetic Engineering: Development of ethylene-insensitive flower lines.

Biodegradable preservatives: Eco-friendly floral preservatives made from plant extracts (e.g., neem, tulasi).

Smart Packaging: Integration of sensors to monitor temperature and ethylene levels during transport.

7. Care Tips for Consumers

Immediate Hydration: Use clean water right after harvest.

Stem trimming & cleaning: Cut at a 45 degrees angle, refresh every 23 days, and avoid leaf submersion.

Water additives: Includes floral food or homemade mixture (sugar + bleach + lemon)

Proper placement: Keep flowers in cool, shaded areas away from direct sunlight, drafts fruits, and heat sources.

Night refrigeration: Storing in cool overnight slows aging.

Conclusion

Enhancing the shelf life of flowers is a multi-disciplinary challenge involving horticultural science, biochemistry, and supply chain management. combination of good agricultural practices, proper post-harvest handling, and modern preservation technologies can significantly extend the vase life of flowers, benefiting producers, retailers, and consumers alike.

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HEALTH BENEFIT OF THUMBAI (*LEUCAS ASPERA*)

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Introduction

Thumbai or *Leucas aspera* is an annual, herb belonging to the family Lamiaceae. It is commonly called Thumba, Thumbai, and Common Leucas. It bears white flowers. The species is found growing in moist places such as stream banks, riversides, swamps, wetlands, ditches, ponds, marshes, etc., in temperate regions. In India, it is distributed throughout the plains, hills, and mountains up to an elevation of about 3000m. This plant has been used for centuries in Chinese medicine to treat various ailments such as fever, cough, sore throat, and colds. The leaves of the plant contain saponins, which are believed to have anti-inflammatory properties. This plant contains saponin compounds, which are known to have anti-inflammatory effects. These compounds also act as antioxidants, helping to prevent damage from free radicals.

The whole plant of L. Aspera contains triterpenoid saponins, flavonoids, alkaloids, steroids, reducing sugars, glucopyranosyl derivatives, diterpene glycosides, isopimarane glycosides, leucoanthocyanidin, leucasperoside A and B, while aerial parts of the plant are reported to contain nicotine, sterols, and two new alkaloids. This plant is used as food in some countries. In addition, it is used as a medicinal herb. It is known to cure coughs, colds, fever, headache, stomach ache, diarrhea, dysentery, indigestion, flatulence, asthma, bronchitis, sinusitis, toothache, earache, eye problems, skin diseases, eczema, psoriasis, rashes, ringworm, warts, boils, and ulcers. *Leucas aspera* has been used traditionally in the treatment of snakebites in the Philippine Islands. The plant contains

leucin, which is known to produce febrifuge properties. In addition, it has been shown that extracts of L. aspera have antibacterial activity against Bacillus subtilus.

Medicinal uses of *Leucas aspera*

1. The medicinal use of *Leucas aspera* includes treating coughs, colds, bronchitis, asthma, sinus infections, and sore throats.
2. This herb also helps treat digestive disorders such as diarrhea, constipation, indigestion, and stomach ulcers.
3. In traditional Chinese medicine, this herb is used to treat coughs, colds, and other respiratory conditions.
4. It is also used to treat stomachaches, heartburn, and other gastrointestinal issues.
5. It also helps to reduce inflammation and pain caused by arthritis and rheumatism.
6. The plant is used to treat acute and chronic wounds. It can be applied directly on the wound or mixed with honey and then applied topically.
7. The plant is also used to treat burns, cuts, bruises, insect bites, and stings.
8. The plant is useful in treating fungal infections such as athlete's foot, jock itch, and ringworm.

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MICRO GREENS BOON TO HUMAN

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Introduction

With the global urban population boom, there is a huge and growing demand for a more sustainable, accessible, and nutritious food supply. Urban farming, especially controlled environment agriculture (*e.g.*, vertical farms, greenhouses, hydroponics, aquaponics, *etc*.) has grabbed the attention of privateas well as government sectors[1]. However, the promises of controlled environment agriculture are still at its early stage and applicable to limited agricultural commodities. Microgreens are among the most adopted crops of controlled environment agriculture, as they can easily be grown hydroponically (the most prevalent indoor farming method) or in soil. Microgreens is a marketing term used to describe young and tender edible seedlings.

They are a relatively new class of vegetables defined as tender immature greens produced from the seeds of vegetables, herbs, or grains, including local varieties and wild species. Microgreens are considered baby plants, falling somewhere between a sprout and baby green (Fig. 1). They shouldn't be confused with sprouts, which do not have leaves. Sprouts also have a much shorter growing cycle of 2–7 days, whereas microgreens are usually harvested 7–21 days after germination, once the plant's first true leaves have emerged. Microgreens are more similar to baby greens in that only their stems and leaves are considered edible. However, unlike baby greens, they are much smaller in size and can be sold before being harvested. This means that the

plants can be bought whole and cut at home, keeping them alive until they are consumed. Microgreens are very convenient to grow, as they can be grown in a variety of locations, including outdoors, in greenhouses and even on your windowsill.

How to grow microgreens

Microgreens are relatively easy to grow on a small scale and can thrive indoors if sunlight is available. People wishing to grow their own microgreens can follow these steps:

a) **Scatter seeds** over an inch of potting soil in a planter dish or tray and cover with another thin layer of soil.

b) **Mist the soil** with water and place near a source of sunlight or a grow light.

c) **Continue to mist** the seeds daily to keep the soil moist.

The microgreens will be ready to harvest in 2–3 weeks. People should take care to cut their greens above the soil line and rinse them well before using them.

Types of Microgreens

There are over 40 varieties of microgreens chosen for their distinct flavours, aesthetic appeal and nutritional values. However, here we have described only 8 easy to grow varieties for your home garden.

1. Sunflower Microgreens

Sunflower microgreens are known for their nutty flavour. They are easy to grow and harvested within two weeks. You can grow sunflower microgreen seeds without much effort in a small container like a used milk carton, salad boxes etc. Choose a seeding mix soil and keep it

moist during the growth process. Sunflower microgreens require proper light and fresh air to grow as well. Hence, once germination starts, remove the lid.

Sunflower microgreens can be used in salads, soups, sandwiches, and dips for adding crunch. You can add them to your shakes and smoothies as well. It is a good source of calcium and iron. Vitamin A, B Vitamins, C, D, and E are available in plenty through these microgreens. They digest easily as well.

Sunflower Micro green

Radish Micro green

Broccoli Micro green

Spinach Micro green

2. Radish Microgreens

They are easy to grow and can be harvested as early as ten days after sowing. The radish microgreen seeds are very easy to grow. Plant seeds evenly and densely on the soil surface.

Radish microgreens rovide flavour, crunchy texture and a touch of spiciness to food. They are rich in the mineral Manganese. And Vitamins like Vitamin B3 (Niacin), Vitamin B6, Vitamin C, and Folate.

3. Pak Choi Microgreens

You can use soil or hydroponic mediums to grow them. The first three days of planting pak choi microgreen seeds need to be blacked out as they are sensitive to light. While harvesting, use a sharp knife directly at the stem.

Pak choi microgreens has a mild flavour that goes well with soups and salads and are full of vitamins C, K, and E, beta-carotene, and iron. They can help prevent cancer cells from forming as it contains glucosinolate.

4. Broccoli Microgreens

Broccoli is another popular microgreens and and easy to grow. They can be harvested in just 6 to 10 days of planting. Its seeds can be grown in shallow containers. They require light and moist soil to grow. Harvest the broccoli microgreens once they are 2 to 3 inches tall by cutting them just above the soil surface. They are one of the healthiest microgreens.

Broccoli microgreens have an earthy flavour and a great addition to soups, sandwiches, etc. for extra crunch. They are far more nutritious than the broccoli crowns that we usually eat. Like any other microgreens, they are rich in vitamins like vitamins A and C as well as iron, calcium, and fibre to name a few. Broccoli microgreens have a protein content of 35 percent.

5. Cabbage Microgreens

Cabbages can also be grown as microgreens at home. You can use any container that is about 2-3 inches deep. Spread out the seeds evenly and densely across the soil. Initially, for 2 to 3 days, the cabbage microgreen seeds require warm moist soil to germinate and after germination, they require proper drainage and ventilation to grow. Cabbage microgreens are ready to harvest when they have open green leaves.

Cabbage microgreens can be used as a garnish for soups, salads, sandwiches, etc. They contain a high level of nutrients mainly, vitamin C, vitamin E and beta carotene. They also contain useful antioxidants.

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NAMO DRON DIDI SCHEME

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Abstract

Agriculture, as the backbone of Indian economy, continues to face challenges in improving productivity, reducing labour dependency and adopting sustainable practices. The integration of modern technologies, such as drones, offers significant potential to address these issues. It also evaluates how schemes like the Namo Drone Didi scheme are being used to advocate for this technology. Namo Drone Didi, a women empowerment initiative to implement drone technology was identified as an effective intervention. It identified challenges including limited training opportunities and inadequate financial support. Retailers and stakeholders also recommended that ensure at least two drones to be made available per block during peak season demand.

Keywords: Drone, Empowerment, Retailers, Technology)

What is Namo Dron Didi Scheme?

Namo Dron Didi Scheme Launched on 30 November 2024.Namo Drone Didi is a central sector scheme aiming to empower women-led Self-Help Groups (SHGs) by equipping them with drone technology to provide agricultural services. The scheme aims to provide drones to 15000 selected Women SHGs during the period from 2024-25 to 2025-2026 for providing rental services to farmers for agriculture purpose (application of liquid fertilizers and pesticides for the present). This initiative is expected to generate an additional income of at least Rs. 1 lakh per year for each SHG, contributing to economic empowerment and sustainable livelihood generation.

Ministry: Ministry of Agriculture & Farmers Welfare.

Key Features of the Scheme

Subsidy to Women DAY NRL-SHGs for Purchase of Drone

80% of Drone Cost as Subsidy upto 8 Lakhs

Loan facility from AIF for remaining cost of Drone

Easy Loan @ 3% interest rate

Drone Pilot training as a part of Drone Package

Chance to earn additional 1 lakh PA through Drone

Renting of Drone Spray Service to Farmers through Women SHGs

Namo Dron Didi Scheme features

S.No.	Title	Features
1.	**Governing Body**	The Namo Didi scheme is governed at the central level by the Empowered Committee of the Secretaries of the Department of Rural Development, Department of Agriculture and Farmers Welfare, Ministry of Civil Aviation, Department of Fertilizers and Ministry of Women and Child Development.
2.	**Monitoring**	Since the introduction of drones in agriculture is at the beginning stage, the states will monitor the interventions, help women SHGs manage an area of at least 2,000 to 2,500 acres in a year and provide handholding support to the women SHGs. The state departments will select SHGs based on agricultural demand, and every SHG is expected to manage around 2,000–2,500 acres annually under their support and guidance.
3.	**Training**	From the selected women SHGs, one member will be selected for a 15-day training consisting of mandatory drone pilot training and additional training for agriculture purposes to apply nutrients and pesticides on crops. Another member or family member of the SHG inclined to take up

repairs of electrical goods, fittings, and mechanical works will be trained as a drone assistant. The drone manufacturers will also provide this training as a package along with the drone supply as per the training schedule provided in the operational guidelines.

Namo Drone Didi scheme eligibility

1) Progressive women SHGs under the DAY-NRLM
2) Women SHGs involved in agricultural activities
3) Qualified women from the SHGs

A qualified woman from the SHGs will receive 15-day training consisting of 5-day mandatory drone pilot training and an additional 10 days of training for agriculture purposes to apply nutrients and pesticides.

A Committee at the state level will select the appropriate clusters and SHGs under the DAY-NRLM to provide drones under this scheme. The Committee comprises of LFC, the State Agriculture Department, the State Mission Directorate of DAY-NRLM and representatives from the ICAR institutions, State Agricultural University (SAU) or Krishi Vigyan Kendras (KVKs).

The state-level Committee will also be responsible for selecting members of the women SHGs for drone pilot and assistant training, availability and existing gap, assessment of district-wise drone usage and identifying the future requirements, providing or ensuring business to selected women SHGs in coordination with the LFCs and pesticide companies, etc.

Namo Drone Didi scheme applies online

The application process for the Namo Drone Didi scheme is yet to begin. The Namo Drone Didi scheme will provide sustainable livelihood and business support to SHGs, allowing them to earn additional income. The scheme will introduce advanced technology in agriculture for enhanced crop yield, improved efficiency, and reduced operation cost, benefiting farmers.

This scheme takes a significant step to advance agricultural practices while empowering women in rural areas. It promises to provide a sustainable income source for SHGs, revolutionise farming practices, and inspire a new generation of women entrepreneurs in rural India.

Benefits of the Namo Drone Didi Scheme

1) **Empowerment of Women:** The scheme provides specialized training in drone technology, equipping women with advanced skills that are increasingly valuable in modern agriculture.

This knowledge enables them to perform tasks like crop monitoring, soil analysis, and precision farming more efficiently.

2) **Enhancement of Agricultural Efficiency:** Drone technology significantly enhances the precise application of pesticides and fertilizers, transforming traditional agricultural practices. Equipped with advanced GPS and sensor technology, drones can be programmed to follow precise flight paths over fields, ensuring even and targeted application. This precision reduces the overuse of chemicals, minimizing environmental impact and lowering costs for farmers.
3) **Skill Development and Knowledge Expansion:** The scheme provides specialized training in drone technology, enabling women to acquire advanced skills in modern agricultural practices such as applying fertilizers, pesticides, and herbicides accurately, ensuring even distribution and optimal usage. Soil and field analysis is streamlined with drones, enabling detailed surveys and fertility assessments. Women can also enhance irrigation management by identifying areas needing more or less water, detecting leaks, and managing water resources efficiently.
4) **Community and Networking Opportunities:** Women can connect with a supportive network of fellow participants, fostering a sense of community and collaboration. They have the chance to join forums and workshops where they can share experiences, challenges, and best practices, enhancing their collective knowledge and skills. The scheme also provides access to industry experts, mentors, and agricultural professionals, creating avenues for mentorship and professional growth.

Challenges & Concerns

1) **Financial Burden on SHGs:** Although the scheme covers 80% of the cost, SHGs must secure the remaining 20% through loans, which could pose a risk for financially vulnerable groups if the economic benefits from drone usage in agriculture fall short of expectations
2) **Limited Training for Technical Complexity:** The 15-day training may be insufficient for SHG members to handle complex tasks like pesticide spraying or troubleshoot unforeseen issues.
3) **Bureaucratic Layers:** Reliance on Lead Fertilizer Companies for coordination could introduce bureaucratic inefficiencies, slowing down the scheme's implementation.

4) **Environmental and Health Risks:** Concerns have been raised about the potential impact on biodiversity, especially in ecologically sensitive areas. For example, conservationists in the Nilgiris district, Tamil Nadu, expressed concerns that aerial spraying could harm pollinators and fragile ecosystems.

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INDIA'S OCEANIC FRONTIERS: UNCLOS FRAMEWORK AND BOUNDARY DELIMITATION IN THE INDIAN OCEAN

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Abstract

India's maritime boundaries in the Indian Ocean are governed by the United Nations Convention on the Law of the Sea (UNCLOS) of 1982, which defines Internal Waters, Territorial Sea, Contiguous Zone, Exclusive Economic Zone (EEZ), and High Seas. Through bilateral and multilateral agreements from 1974 to 2014, India has demarcated boundaries with Sri Lanka, Maldives, Indonesia, Thailand, Myanmar, and Bangladesh, using principles of equidistance or modified equidistance. These delimitations ensure jurisdictional clarity, resource management, and maritime security across strategically significant waters.

Keywords: UNCLOS, Exclusive Economic Zone, Maritime Boundary, Indian Ocean, Equidistance Principle

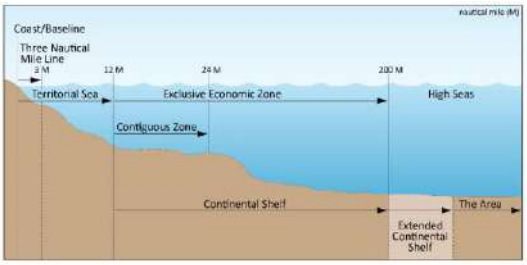
Introduction

The United Nations Convention on the Law of the Sea (UNCLOS) of 1982, often referred to as the "Law of the Sea" establishes a comprehensive framework for the division and governance of marine areas. It classifies maritime spaces into five principal zones: Internal Waters, Territorial Sea, Contiguous Zone, Exclusive Economic Zone (EEZ), and the High Seas.According to the 1982 Law of the Sea Convention off site link, the baseline established in conformity with customary international law is used to measure the width of the territorial sea, contiguous zone, and EEZ. The area, where land and sea meet is called the 'Maritime Zone', sometimes referred to as the Marine or Coastal Zone. In order to manage marine resources, maintain maritime safety, and safeguard the environment, these zones must be clearly defined.

About 71% of the Earth's surface is made up of water, which is separated into five oceans:

1. Pacific Ocean (155.6 million km²)
2. Atlantic Ocean (85.1 million km²)
3. Indian Ocean (73.5 million km²),
4. Arctic Ocean (14.0 million km²)
5. Southern Ocean (20.3 million km²), also known as the Antarctic Ocean.

Maritime zones:



Maritime Zones under International Law (Image credit: U.S. Department of State as modified by NOAA to add Three Nautical Mile Line)

Baseline

The baseline refers to the low-water line along a nation's coast, as officially recognized by that coastal state.

Internal Waters

Internal waters are located on the landward side of the baseline from which the territorial sea's breadth is measured.

Rights of the Coastal State: A coastal state exercises complete sovereignty over these waters, similar to its authority over land territory. Examples include bays, ports, inlets, rivers, and even lakes that connect to the sea. There is no automatic right of innocent passage through internal waters.

Territorial waters/ Territorial sea:

Territorial waters are the bodies of water next to a country's coastline/ baseline, considered part of its territory and under its control, usually extending up to 12 nautical miles (nm) from the baseline of the shore.

[A nautical mile based on Earth's circumference equals one minute of latitude and is slightly longer than a land mile (1 nm = 1.1508 miles or 1.85 km)**].**

Contigous zone:

The contiguous zone is a maritime area adjacent to and extending beyond a nation's territorial sea.

Rights of the Coastal State: The coastal state can exercise control to prevent and address violations of its customs, fiscal, immigration, and sanitary laws within its territory or territorial waters.

Exclusive Economic zone:

An "exclusive economic zone" (EEZ) refers to a maritime area, usually extending 200 nautical miles (230 miles) from a country's territorial sea, The idea of an EEZ was established by the 1982 United Nations Convention on the Law of the Sea.

Rights of the Coastal State : Within this zone, the state holds sovereign rights to explore, exploit, conserve, and manage natural resources both living and non-living found in the seabed, subsoil, and waters above. It may also engage in activities such as generating energy from water, currents, and wind.

International waters:

International waters, also known as the high seas, are areas of the ocean not governed by any one nation's jurisdiction. These waters begin beyond a nation's territorial sea, which extends 12 nautical miles (22.2 km) from its coastline. International waters make up about 50% of the Earth's surface and include all oceans and seas that lie outside the Exclusive Economic Zones (EEZs) of coastal nations, which stretch up to 200 nautical miles (370 km) from the coast.

Comaparative sizes of the various maritime zones:

Areas of the Earth covered by the Oceans	approx. 335.0 million km2
Territorial Seas	22.4 million km2
Contiguous Zones	6.6 million km2
Exclusive Economic Zones	101.9 million km2
High Seas	200.4 million km2
Total areas under national jurisdiction excluding extended continental shelves beyond 200 nm	131.0 million km2

Source: UNEP/GRID-Arendal, Continental Shelf: The Last Maritime Zone at 28 (Mar. 2011).

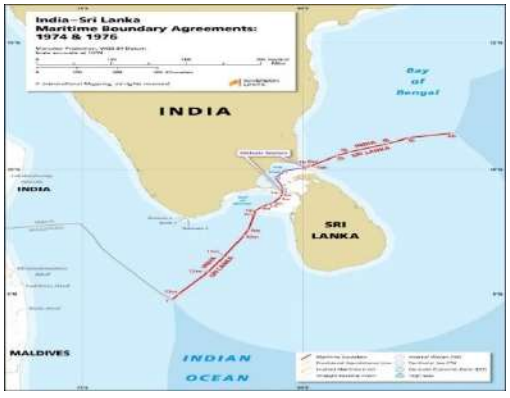
Maritime Boundries of India with Countries in Indian Ocean:

Time line :

Year	Event / Agreement
1974	India–Sri Lanka Maritime Boundary Agreement (1st)
1974 (Dec 17)	India–Indonesia Maritime Boundary Agreement (1st)
1976	India–Sri Lanka Maritime Boundary Agreement (2nd)
1976 (Dec 28)	India–Maldives Maritime Boundary Agreement
1977	Extension of India–Indonesia Maritime Boundary
1978 (June 22)	India–Indonesia–Thailand Tripoint Agreement
1978 (June 22)	India–Thailand Maritime Boundary Agreement
1978 (June 8)	India–Maldives Boundary Comes into Effect
1986 (Dec 23)	India–Myanmar Maritime Boundary Agreement
1993 (Oct 27)	India–Myanmar–Thailand Tripoint Agreement
2014 (July 7)	Bangladesh–India Maritime Dispute Resolved

India–Sri Lanka

The maritime boundary between India and Sri Lanka was defined through two bilateral agreements signed in 1974 and 1976. This boundary stretches approximately 288 km, from the tripoint with the Maldives in the west to the 200 nautical mile limit of both nations in the east. The section of the boundary passing through the Palk Strait, considered historic waters, was set based on the principle of modified equidistance in the 1974 agreement. The boundary in the Indian Ocean/Gulf of Mannar and the Bay of Bengal was established in 1976 and follows a simplified equidistance line.

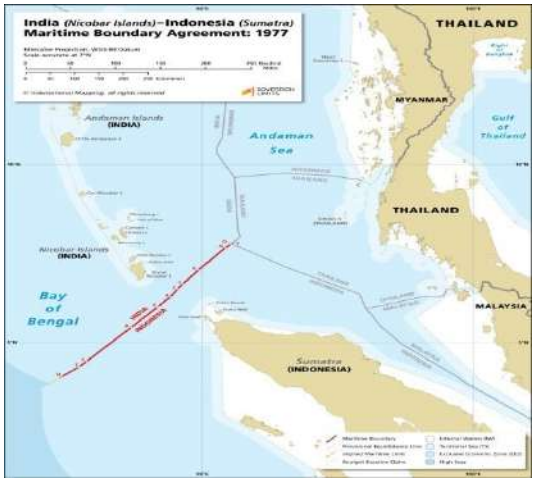


India–Maldives

The maritime boundary between India and the Maldives was defined through a bilateral agreement signed on December 28, 1976, which came into effect on June 8, 1978. This boundary spans 545 nautical miles and separates the exclusive economic zones of both countries. It was established using a modified equidistance line.

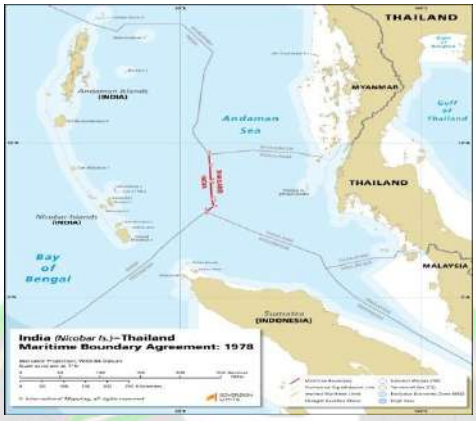
India–Indonesia:

The initial segment of the maritime boundary closest to the relevant islands of both nations was defined through a bilateral agreement signed on December 17, 1974. The boundary was later extended in 1977, both northeast into the Andaman Sea and southwest into the Indian Ocean. The India–Indonesia boundary is nearly 300 nautical miles long, covering the overlapping maritime zones created by India's Nicobar Islands and Indonesia's Sumatra Island. On June 22, 1978, India, Indonesia, and Thailand signed an agreement to fix the tripoint location in the Andaman Sea at point T.



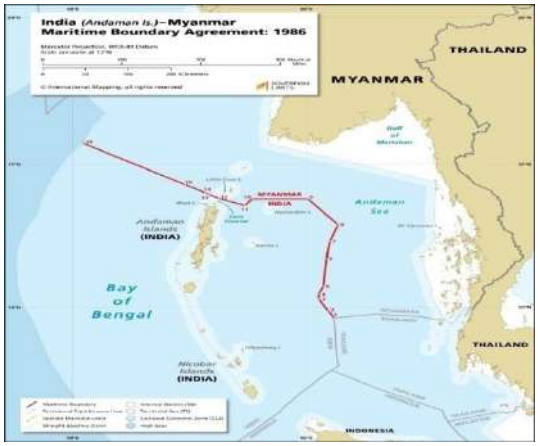
India–Thailand

The maritime boundary between India's Nicobar Islands and Thailand's Simlan Islands follows the principle of equidistance and stretches from a tripoint with Indonesia in the south to a tripoint with Myanmar in the north. This boundary runs approximately 115 nautical miles north to south through the southern Andaman Sea. India and Thailand reached an agreement on this boundary on June 22, 1978, and later that same day, a tripoint agreement with Indonesia was made. The final agreement on the northern tripoint with Myanmar was reached on October 27, 1993.



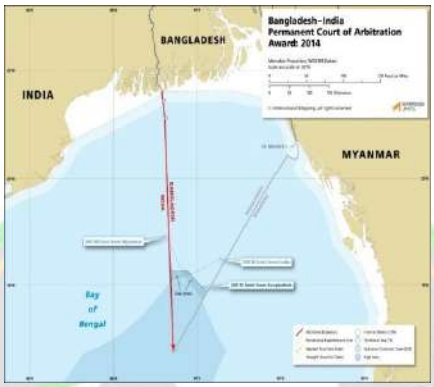
India–Myanmar

Myanmar and India A bilateral agreement concluded on December 23, 1986, created the maritime border between India and Myanmar, which passes through the Bay of Bengal, Coco Channel, and Andaman Sea. The border, which runs 593 nautical miles along a modified equidistance line, divides Myanmar's maritime rights from India's Andaman and Nicobar Islands. The tripoint with Thailand, which was formally formed by a trilateral agreement concluded on October 27, 1993, marks the beginning of the boundary at Point 1.



Bangladesh–India

The long-standing maritime dispute between Bangladesh and India was resolved on 7 July 2014, when the Permanent Court of Arbitration issued its final award. The Tribunal began by identifying the land boundary terminus, as defined in the 1947 Radcliffe Award, which served as the starting point for the maritime delimitation. Within the territorial sea, the boundary was drawn using the equidistance method. Beyond this zone, the line was adjusted slightly southward along a directional azimuth of N 177° 30′ E, extending until it met the Bangladesh–Myanmar maritime boundary on the outer continental shelf.



Conclusion

India's clearly defined maritime boundaries are the result of decades of diplomacy, adherence to international maritime law, and cooperation with neighboring states. These boundaries not only safeguard sovereign rights over vast marine areas but also provide a legal basis for the sustainable exploitation of living and non-living resources, including fisheries, hydrocarbons, and renewable energy. By reducing the scope for jurisdictional disputes, they contribute to regional stability, strengthen maritime security, and facilitate scientific research and environmental conservation in one of the world's most strategically vital oceanic regions. As global interest in the Indian Ocean grows, maintaining these well-established boundaries will remain critical for protecting India's economic and security interests while fostering collaborative maritime governance.

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BIOCHAR: A SUSTAINABLE SOLUTION FOR SOIL HEALTH IMPROVEMENT

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Introduction

Healthy soils form the foundation of agricultural productivity, biodiversity conservation, and climate resilience. However, decades of unsustainable land use, over-reliance on chemical inputs, deforestation, and climate change have degraded soils worldwide. The **FAO estimates** that over 33% of the Earth's soils are moderately to highly degrade due to erosion, nutrient depletion, salinization, and contamination. In this context, finding sustainable, long-lasting solutions to restore and maintain soil health has become a global priority.

One promising approach is **biochar**—a stable, carbon-rich material produced from the pyrolysis of biomass. Unlike conventional soil amendments that may degrade or leach over time, biochar remains in the soil for decades to centuries, enhancing its physical, chemical, and biological properties while contributing to climate change mitigation. It is not merely a soil conditioner but a **multifunctional tool** that addresses agricultural productivity, waste management, and greenhouse gas reduction simultaneously.

1. What Is Biochar and How Is It Produced?

Biochar production involves the **thermal decomposition of organic matter** in a low-oxygen environment a process known as **pyrolysis**. Biomass sources can range from agricultural residues (rice husks, corn stover, sugarcane bagasse) to forestry waste (sawdust, bark) and even animal manure. The feedstock's chemical composition significantly influences the biochar's characteristics.

Key production factors:

- **Temperature**:
  - *Low-temperature pyrolysis* (300–500 °C) produces biochar with higher volatile matter and nutrient content, but less structural stability.
  - *High-temperature pyrolysis* (500–700 °C) yields more aromatic carbon structures, enhancing stability and surface area.
- **Residence time**: Longer pyrolysis times allow for greater carbonization and pore development.
- **Heating rate**: Fast pyrolysis yields more bio-oil and less biochar, while slow pyrolysis maximizes solid carbon yield.

2. Physical Impacts on Soil Structure

Biochar's porous, lightweight structure influences multiple **physical properties** of soil:

- **Porosity & Aeration**: Biochar's high internal surface area allows greater air circulation in compact soils, benefiting root respiration.
- **Water Retention**: Biochar can hold up to 6 times its weight in water, reducing drought stress in sandy soils.
- **Bulk Density Reduction**: Amending clayey soils with biochar decreases bulk density, facilitating root penetration.
- **Soil Aggregation**: The presence of biochar particles improves soil aggregate stability, reducing erosion risk.

3. Chemical Benefits: Nutrients and pH Regulation

Biochar modifies **soil chemistry** in beneficial ways:

- **pH buffering**: Alkaline biochars can neutralize acidic soils, increasing nutrient solubility.
- **Cation Exchange Capacity (CEC)**: Functional groups on biochar surfaces hold nutrient cations, reducing leaching losses.
- **Nutrient Retention & Release**: Nutrients such as phosphorus, potassium, and ammonium are retained and released slowly over time.
- **Contaminant Immobilization**: Heavy metals like cadmium (Cd^{2+}), lead (Pb^{2+}), and arsenic (As^{3+}) can bind to biochar surfaces, reducing toxicity.

4. Biological Impacts: Microbial and Plant Relationships

The biological dimension of soil health is equally crucial:

- **Microbial Habitat Creation**: Biochar's pores provide shelter for bacteria and fungi, protecting them from predators and desiccation.
- **Enhanced Microbial Diversity**: Studies report increased abundance of beneficial bacteria such as *Bacillus* and *Pseudomonas* after biochar application.
- **Promotion of Mycorrhizal Symbiosis**: Biochar enhances colonization by arbuscular mycorrhizal fungi, which improve plant nutrient uptake.
- **Disease Suppression**: Biochar can reduce the incidence of soil-borne diseases by altering microbial community structure and producing inhibitory compounds.

5. Environmental Co-Benefits: Carbon Sequestration and Mitigation

Biochar is a **climate-smart** amendment:

- **Long-Term Carbon Storage**: Carbon in biochar exists primarily in aromatic rings, highly resistant to microbial decomposition—remaining in soils for centuries.
- **Reduced Greenhouse Gas Emissions**: Biochar-amended soils emit less nitrous oxide (N_2O) and methane (CH_4).
- **Waste Management Solution**: Pyrolyzing crop residues prevents open-field burning, which is a major source of air pollution.
- **Synergy with Bioenergy**: The syngas and bio-oil from pyrolysis can be used as renewable energy, making the process circular.

6. Economic and Practical Considerations

The **economics** of biochar adoption depend on:

- **Production Costs**: Larger, centralized pyrolysis plants can lower per-unit costs but may face high transportation expenses for feedstock and final product.
- **Yield Gains & Fertilizer Savings**: Over several cropping seasons, biochar can reduce the need for lime and fertilizers, offering cost savings.
- **Carbon Credit Opportunities**: Verified carbon storage through biochar can be monetized in voluntary carbon markets.
- **Local Context**: In rural areas with abundant crop residues, low-tech pyrolysis kilns make small-scale production feasible.

7. Challenges and Limitations

Despite strong potential, biochar adoption faces hurdles:

- **Variability in Quality**: Poorly produced biochar may contain harmful compounds like polycyclic aromatic hydrocarbons (PAHs).
- **Context Dependency**: Biochar's benefits vary with soil type, climate, and crop system.
- **Initial Investment**: Farmers may be hesitant due to upfront costs without immediate returns.
- **Knowledge Gaps**: Many farmers are unaware of optimal application rates or methods.

Mitigation strategies:

- Developing **biochar quality standards** (e.g., European Biochar Certificate).
- Providing farmer training and demonstration trials.
- Encouraging co-application with compost or manure to maximize benefits.

8. Future Directions and Innovations

Areas of future development include:

- **Designer Biochars**: Tailoring surface chemistry to target specific soil constraints (e.g., phosphorus-enriched biochar for P-deficient soils).
- **Integration with Precision Agriculture**: Using remote sensing to identify areas needing biochar application.
- **Policy Integration**: Including biochar in national climate strategies and sustainable agriculture programs.
- **Long-Term Field Trials**: Multi-decade monitoring to assess cumulative impacts on yields, soil health, and carbon sequestration.

9. Summary of Key Benefits

Physical Benefits:

- Improves structure, aeration, and water retention.
- Reduces compaction and erosion.

Chemical Benefits:

- Increases nutrient availability and retention.
- Buffers soil pH and immobilizes contaminants.

Biological Benefits:

- Enhances microbial diversity and root symbiosis.
- Suppresses certain soil-borne diseases.

Environmental Benefits:

- Sequesters carbon for centuries.
- Reduces GHG emissions.
- Manages agricultural waste sustainably.

Economic Benefits:

- Increases yields and reduces input costs.
- Opens opportunities for carbon credit revenue.

Conclusion

Biochar offers a rare combination of **agronomic, environmental, and economic benefits**, making it a highly promising tool for sustainable soil management. By improving soil physical structure, enhancing nutrient dynamics, fostering beneficial biology, and providing long-term carbon storage, biochar contributes directly to climate change mitigation and agricultural resilience.

However, to achieve large-scale impact, stakeholders must address challenges related to quality assurance, cost barriers, and context-specific application guidelines. Policy support, farmer education, and integrated research are essential for biochar's mainstream adoption. If deployed wisely—combining scientific knowledge, local resource availability, and supportive policy frameworks—biochar can play a transformative role in restoring degraded soils, boosting food security, and creating a climate-positive agricultural future.

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MEDICINAL MUSHROOM CULTIVATION AND ITS POTENTIAL ACTIVITIES

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Introduction

Cordyceps is the largest and most diverse genus classified in the family Clavicipitaceae as regards to the number of its species, the morphology and the variation in its host, with over 750 identified species . It is a well-known ascomycetes parasitic fungus with all the known species acting as endoparasitoids mainly on insects and other arthropods, with a few on other fungi . The name Cordyceps was obtained from the Greek word “kordyle” meaning “club”, and the Latin stem “-ceps” meaning “head”. All Cordyceps species have similar life cycle and have developed mechanisms to invade their host and grow on them, the major differences being the locality where they grow and the host insect they infect. Cordyceps species remain dormant in the soil until they get in contact with a host. Besides their morphological diversity, they also differ widely in cultivability. They produce a superficial to completely immersed perithecia on stipitate and often clavate to capitate stromata, which distinguishly characterizes Cordyceps from other genera in the family, and its ecology as a pathogen of arthropods and the fungal genus Elaphomyces About 20 Cordyceps species parasitizes on the genus Elaphomyces, while the remaining species parasitizes on insects and other arthropods that belongs to the class Arachnida, Coleoptera, Hemiptera, Hymenoptera, Isoptera and Lepidoptera.

A few of the species in the genus have the ability to infect a wide range of host (species in several families or orders of arthropods). Howbeit, a large number of the Cordyceps species are limited to infecting only a single host species or few closely related species. Cordyceps develops highly specific and sophisticated mechanisms to evade the host immune system and harmonize their life cycle parameters to that of its host for the purpose of survival and

multiplication. This mechanism of survival has resulted in the production of several unique secondary metabolites in response to the host defense which are promising sources for new drug discovery.

Macroscopic Features:

- **Stromata:**

These are the fruiting bodies, often club-shaped and varying in color from yellowish to reddish-orange.

- **Perithecia:**

These are the flask-shaped structures where spores are produced, embedded within the stroma.

- **Host Specificity:**

Cordyceps fungi are typically host-specific, with different species infecting various insects and spiders.

Microscopic Features:

- **Asci:**

These are sac-like structures that contain the ascospores.

- **Ascospores:**

These are the sexual spores produced by the asci. They can be filiform (thread-like) and septate (divided into segments), and sometimes disarticulate into part-spores.

- **Conidiogenous structures:**

Some Cordyceps species also exhibit asexual conidiation, forming structures like Verticillium-like or Paecilomyces-like structures.

- **Hyphae:**

These are the thread-like filaments that make up the fungal body, and can have distinct characteristics in different species.

In addition to these morphological characters, Cordyceps also exhibits:

- **Unique life cycle:**

Cordyceps fungi typically infect their host, grow inside it, and eventually emerge to produce fruiting bodies, often after the host has died.

- **Specific habitat:**

They are commonly found in soil or on decaying organic matter, where their insect or spider hosts reside.

Examples of Cordyceps species and their characteristics:

- **Cordyceps militaris:**

Characterized by solitary or several stromata, yellowish to reddish-orange fertile parts, semi-immersed and ovoid perithecia, cylindrical asci, filiform ascospores with multi-septa, and short part-spores**.**

- **Cordyceps gunnii:**

Has a cylindrical, stout, and rough stroma, with a sterile bulgy or branched apex.

- **Cordyceps tenuipes:**

Features conspicuous synnemata (stalked clusters of conidiophores) that are simple, furcate (branched), or irregularly branched.

- **Cordyceps ningxiaensis:**

A new species found in China, associated with fly pupae and distinguished by its morphology and phylogenetic analysis.

Cordyceps, a fungus traditionally used in Chinese medicine, is believed to possess a variety of medicinal properties including anti-cancer, anti-inflammatory, and antihyperglycemic effects. It is also associated with anti-fatigue and immunomodulatory properties. While many studies have focused on the effects of cordycepin, a bioactive compound from Cordyceps, research on other active metabolites and their neuroprotective activities is ongoing.

Potential Medicinal Properties of Cordyceps:

- **Anticancer:** Cordyceps has been studied for its potential to inhibit cancer cell growth and proliferation.
- **Anti-inflammatory:** It may help reduce inflammation in the body, potentially aiding in conditions like arthritis.
- **Antihyperglycemic:** Cordyceps may help lower blood sugar levels, making it potentially beneficial for individuals with diabetes.
- **Antifatigue:** It has been traditionally used to combat fatigue and enhance physical performance.
- **Immunomodulatory:** Cordyceps may help regulate the immune system, potentially improving its function and response to various conditions.
- **Hepatoprotective:** It may help protect the liver from damage and improve its function.

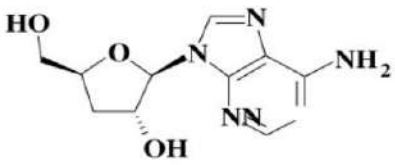
- **Spermatogenic:** Some studies suggest it may have a positive effect on male sexual function.
- **Hypolipidemic:** It may help lower levels of lipids (fats) in the blood, potentially benefiting cardiovascular health.
- **Antihypertensive:** Cordyceps may help lower blood pressure.
- **Nephroregulatory:** It may have a protective effect on the kidneys.
- **Antifibrosis:** It may help prevent or reduce the formation of scar tissue.
- **Neuroprotective:** Some studies indicate potential benefits for neurological health and protection against neurodegenerative diseases.

Bioactive Compounds in Cordyceps:

Cordyceps contains various bioactive compounds that contribute to its medicinal properties, including:

- **Cordycepin:**

A nucleoside with anti-cancer, anti-inflammatory, and other pharmacological activities.



Cordycepin
(3'-deoxyadenosine)

Fig 1 . Structure of cordycepin

- **Polysaccharides:**

These have been shown to possess immunomodulatory, antitumor, antioxidant, and hypoglycemic effects.

- **Other Compounds:**

Sterols, flavonoids, cyclic peptides, phenolic compounds, bioxanthracenes, polyketides, and alkaloids are also present.

- While Cordyceps shows promise in various areas, more human clinical trials are needed to confirm these benefits and determine appropriate dosages.

- Some individuals may experience side effects, such as dry mouth, bloating, rashes, or loss of appetite.
- Individuals with autoimmune conditions or those taking anticoagulation medications should exercise caution and consult with a healthcare professional before using Cordyceps.

Cultivating Cordyceps, particularly Cordyceps militaris, involves a few key stages: preparing the substrate, inoculating with mycelium, and managing environmental conditions to encourage fruiting. Two main methods are used: solid-state fermentation (using grains or insects) and liquid fermentation.

Solid-State Fermentation (Grains or Insects):

1. Substrate Preparation:

Grains like brown rice or insects like silkworm pupae are common substrates. They are sterilized to eliminate competing organisms.

2. Inoculation:

The sterilized substrate is inoculated with a Cordyceps mycelial culture.

3. Incubation:

The inoculated substrate is incubated under controlled conditions (temperature, humidity, light) to allow the mycelium to colonize.

4. Fruiting:

Once the substrate is fully colonized, the conditions are adjusted to promote fruiting body (the mushroom) development. This may involve changes in light, temperature, and humidity.

5. Harvesting:

The fruiting bodies are harvested, dried, and can be used for various purposes.

Liquid Fermentation:

1. **Liquid Medium Preparation:** A nutrient-rich liquid medium is prepared.
2. **Inoculation:** The liquid medium is inoculated with Cordyceps mycelium.
3. **Incubation:** The liquid culture is incubated under specific conditions (temperature, shaking speed).
4. **Harvesting:** The mycelium can be harvested for its bioactive compounds (like cordycepin and polysaccharides).

Key Considerations:

- **Strain Selection:**

Different strains of Cordyceps may have different substrate preferences and growth requirements.

- **Substrate Choice:**

The choice of substrate (grains, insects, etc.) can significantly impact the yield and quality of the final product.

- **Environmental Control:**

Maintaining the correct temperature, humidity, and light conditions is crucial for successful cultivation.

- **Sterility:**

Maintaining a sterile environment is essential to prevent contamination from other microorganisms.

- **Strain Selection:**

The specific Cordyceps species and strain chosen will affect the cultivation process and the resulting product.

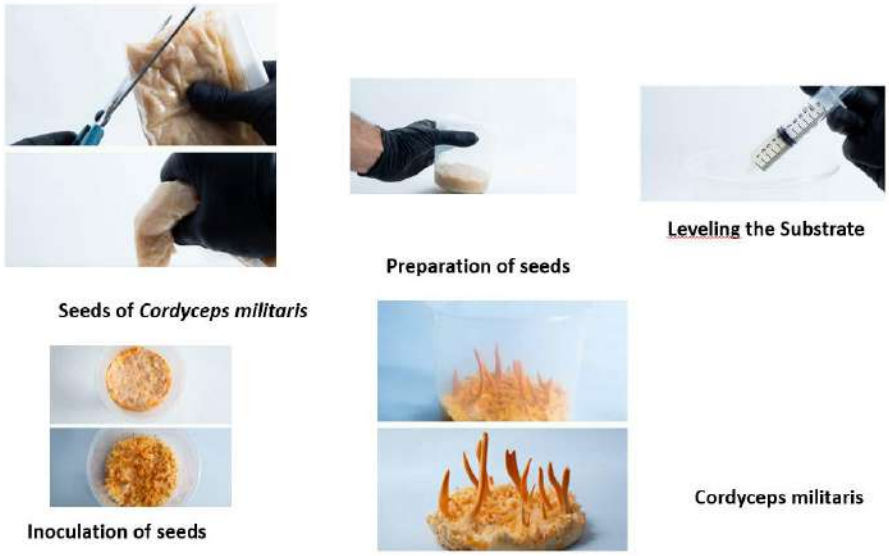


Fig 2.Cultivation of cordyceps melitaris

Bioactive Compound Production:

Different cultivation methods can impact the levels of bioactive compounds like cordycepin and polysaccharides.

Value-added products derived from Cordyceps

Nutraceuticals:

Cordyceps extracts and powders are used in dietary supplements, often marketed for their potential health benefits like improved energy, immune support, and antioxidant properties.

Functional Foods:

Cordyceps is incorporated into various food products like beverages, snacks, and health bars to enhance their nutritional value and perceived health benefits.

Pharmaceuticals:

Cordycepin, a key bioactive compound, is being investigated for its potential anticancer and other pharmacological properties, with some research focusing on its modified forms like NUC-7738 from ScienceDirect.com.

Cosmetics:

Some research explores the use of Cordyceps extracts in cosmetic products for their potential antioxidant and anti-aging properties.

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CRISPR/CAS9 MEDIATED GENOME EDITING IN PLANTS

Article ID: AG-V05-I08-104

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Abstract

High temperature is fast becoming a major abiotic stress affecting plant growth, morphology and productivity. Heat stress is defined as hot temperatures beyond a threshold level for a period of time resulting in irreversible damage to plant growth and development. Generally, temperature above 10–15 °C is considered heat shock or heat stress. Plants express a variety of responses to high temperatures. Though heat stress affects plant growth at all developmental stages, later phenological stages in particular anthesis and grain filling, are generally more susceptible. Temperature stress is an emerging concern with regard to global food security. Hence, addressing heat stress through biotechnological approaches is the need of the hour.

Genetic engineering for high-temperature tolerance in plants can be achieved either by over-expressing genes of heat shock protein or altering levels of heat shock transcription factor as well as by elevating levels of osmolytes. Over the period of research, it had been concluded that *Hsps* helps in minimising the damage to cell proteins hence improving the heat tolerance. Successful examples of enhancement of the high temperatures tolerance includes genetic engineering of glycine betaine synthesis in Arabidopsis, or suppression of *OsMDHAR4* in rice; expression of rice heat stress transcription factor *OsHsfA2e* in transgenic Arabidopsis. Similarly reports on the expression of transcription factor *OsbZIP46CA1* and SAPK6 (protein kinase) resulted in improved tolerance to heat and cold stress in rice. Recent reports on rice indicated that over expression of protein disulfide isomerase gene from *methano thermobacter thermauti*

trophicus enhanced heat tolerance in rice. Furthermore, Yu *et al*. (2017) have demonstrated that over expression of poplar genes *PtPYRL1* and *PtPYRL5* enhances tolerance to drought and cold stresses by activating the ABA signalling pathway. Esmaeili *et al*. (2019) had proven enhanced tolerance to drought, salt, and heat stresses by co-over expression of *AVP1/OsSIZ1* and provides the proof-of-concept that double gene over expression performs significantly better than *AVP1*-overexpressing plants and *OsSIZ1*-overexpressing plants.

Manipulation of genes, transcription factors and signalling/metabolic pathways associated with cold and heat tolerance can effectively generate-tolerant crop varieties. Genome editing can be a valuable option for rapid and effective generation of abiotic stress-tolerant crop varieties. Few successful reports using CRISPR/Cas9 genome editing to confer abiotic stress tolerance were demonstrated in Arabidopsis, Rice and other crops. Miao *et al*. (2018) had worked on the *OsPYL* (abscisic acid receptor gene family) and successfully created *pyl1/4/6* triple knockout rice by CRISPR/Cas9 editing, resulted in increased grain yield, greater high-temperature tolerance.

Keywords: *CRISPR/Cas9, Tolerance, Abiotic stress, Double gene, PtPYRL1, Phenological stage*

Major Challenges for the Application of Genome Editing in Crops:

(i) *Off targets*

Though several attempts have been made to reduce the off-target effects in the gene-edited plants such as identification of cas9 orthologous and cas9 variants, still, the specificity issues persist. It comes to more concern while considering medical applications than in crop plants.

(ii) *Protocol optimisation*

It is difficult to develop a suitable tissue culture protocol for crops such as cotton, tree species including coconut, citrus, cashew, pomegranate, mango and woody species etc. Several studies are being conducted to improve tissue culture protocol for these species and applied to genome editing (Jia *et al*. 2019).

(iii) *Public acceptance*

Although genome editing has obtained more popularity among the science community and applied to many crop systems for developing improved lines, all the research is at the laboratory level. Regulatory measures to determine the gene-edited crops as transgene-free crops

or genetically modified crops is still uncertain in many countries and there is no internationally accepted frameworks are available in the current scenario (Mao *et al*. 2019).

Application of CRISPR/Cas9 mediated genome editing in plants began in the year 2013. The first reported modification of a plant using a CRISPR/Cas system was by Shan *et al*. (2013). In the same year, Li *et al*. (2013) and Nekrasov *et al*. (2013) reported genome editing in *Arabidopsis* and *Nicotiana benthamiana* (Li *et al*. 2013; Nekrasov et al. 2013). A number of examples in recent years have demonstrated widespread application of CRISPR/Cas9 mediated genome editing for crop improvements.

Proof of Concept Studies

Some of the proof of concept studies on the successful use of CRISPR/Cas9 editing in various plants have been listed as follows: *Arabidopsis*, tobacco, sorghum and rice (Jiang *et al*. 2013; Li *et al*. 2013; Nekrasov *et al*. 2013), wheat (Jiang *et al*. 2013; Shan *et al*. 2013), rice (Barman *et al*. 2019; Jiang *et al*. 2013; Lee *et al*. 2019a, b, c; Li *et al*. 2016; Saika *et al*. 2019; Xu *et al*. 2015; Zhang *et al*. 2014; Zhou *et al*. 2014), tomato (Bari *et al*. 2019; Brooks *et al*. 2014; D'Ambrosio *et al*. 2018; Ito *et al*. 2015; Li *et al*. 2018a, b, c, d, 2019a, b; Ortigosa *et al*. 2019; Pan *et al*. 2016; Tashkandi *et al*. 2018; Veillet *et al*. 2019; Wang *et al*. 2019a, b; Yu *et al*. 2017), sweet orange (Jia and Wang 2014), maize (Char *et al*. 2017; Chen *et al*. 2018; Doll *et al*. 2019; Feng *et al*. 2016, 2018; Lee *et al*. 2019a, b, c; Li *et al*. 2017a, b; Liang *et al*. 2014; Malzahn *et al*. 2019; Qi *et al*. 2016; Shi *et al*. 2017; Svitashev *et al*. 2016; Zhu *et al*. 2016) and soybean (Al Amin *et al*. 2019; Bao *et al*. 2019a, b; Cai *et al*. 2015, 2018a, b, 2019; Chilcoat *et a*l. 2017; Do *et al*. 2019; Du *et al*. 2016; Jacobs *et al*. 2015; Li *et al*. 2018a, b, c, d, 2019a, b; Liu *et al*. 2019; Michno *et al*. 2015; Sun *et al*. 2015). A more detailed list of recent publications in this field is provided in **Tables 1 and 2**.

Table 1 Application of CRISPR/Cas genome modifications in important crop plants

Host plant	Modification	Reference
Brassica napus (Oilseed rape)	CRISPR-Cas9 construct used to target two *ALCATRAZ* (*ALC*) homoeologs. Knocking out *ALC* increase shatter resistance to avoid seed loss during mechanical harvest	Braatz *et al*. (2017)
Brassica napus (Oilseed rape)	CRISPR/Cas9 mutagenesis of *BnCLV3* produced more leaves and multilocular siliques with a significantly	Yang *et al*. (2018)

	higher number of seeds per silique and a higher seed weight than the wild-type and single mutant plants, potentially contributing to increased seed production	
Brassica napus (Oilseed rape)	Examined the mutation efficiency of the CRISPR/Cas9 method for 12 genes and also determined the pattern, specificity and heritability of these gene modifications in *B. napus*	Yang *et al*. (2017)
Oryza sativa (Rice)	Engineered CRISPR/Cas was active in creating DSBs when stably expressed in rice plants. CRISPR/Cas was used to achieve targeted genome modifications in both dicot and monocot plants	Feng *et al*. (2016)
Hordeum vulgare (Barley)	Employed SpCas9-mediated knockout strategy to functionally study *HvMORC1*, one of the Microrchidia (MORC) proteins that contribute in genome stabilization in monocotyledonous and dicotyledonous plants	Kumar *et al*. (2018)
Manihot esculenta (Cassava)	Used CRISPR/Cas9 technology in cassava, the *Phytoene desaturase* (*MePDS*) gene, which is a plant carotenoid biosynthetic enzyme was targeted in two cultivars	Odipio *et al*. (2017)
Manihot esculenta (Cassava)	CRISPR/Cas9-mediated genome editing was employed to generate *eif4e, ncbp-1, ncbp-2,* and *ncbp-1/ncbp-2* mutants in cassava cultivar 60,444 which delayed and attenuated cassava brown streak disease (CBSD) aerial symptoms and reduced severity and incidence of storage root necrosis as well	Gomez *et al*. (2019)
Gossypium hirsutum (Cotton)	CRISPR/Cas9 genome editing technology was used to knock out the cotton arginase gene (*GhARG*) to improve lateral root formation	Wang *et al*. (2018a, b)

Gossypium hirsutum (Cotton)	Cassette of sgRNA was designed to target Cotton leaf curl disease (CLCuD)-associated begomovirus complex and satellite molecules	Iqbal *et al*. (2016)
Cucumis sativus (Cucumber)	Generated a gynoecious cucumber line through CRISPR/Cas9-mediated mutagenesis of *CsWIP1*	Hu *et al*. (2017)
Cucumis sativus (Cucumber)	Development of virus resistance in cucumber using sgRNA technology by disrupting the function of the recessive *eIF4E* (eukaryotic translation initiation factor 4E) gene	Chandrasekaran *et al*. (2016)
Glycine max (soybean)	Demonstrated the effectiveness of CRISPR/Cas9 system in soybean by knocking-out a green fluorescent protein (GFP) transgene and modifying nine endogenous loci	Jacobs *et al*. (2015)
Glycine max (soybean)	Cas9-guide RNA (gRNA) was successfully applied to generate targeted mutagenesis, gene integration, and gene editing	Li *et al*. (2015)
Vitis vinifera (Grape)	Knockout of *VvWRKY52* in grape to increase the resistance to *Botrytis cinerea*	Wang *et al*. (2018a, b)
Nicotiana benthamiana	Resistance to tomato yellow leaf curl virus (TYLCV) using CRISPR/Cas9 system	Ali *et al*. (2015)
Brassica napus (Oilseed rape)	Modification of a fatty acid desaturase 2 gene (*FAD2*), which encodes an enzyme that catalyzes the desaturation of oleic acid, in *Brassica napus* cv. Westar using the CRISPR/Cas9 system	Okuzaki *et al*. (2018)
Citrus sinensis (Orange)	Demonstrated CRISPR/Cas9-mediated promoter editing strategy for generation of canker-resistant citrus cultivars	Peng *et al*. (2017)
Oryza sativa (Rice)	SgRNAs directed Cas9 to induce sequence-specific genome modifications in the rice	Shan *et al*. (2013)

Oryza sativa (Rice)	Created short life cycle in Kitaake, a *japonica* rice variety by targeting *CAO1* and *LAZY1* gene	Miao *et al*. (2013)
Oryza sativa (Rice)	Engineered guide RNAs were shown to direct the Cas9 nuclease for precise cleavage at the desired sites and introduce mutation (insertion or deletion) by error-prone non-homologous end-joining DNA repair	Xie and Yang (2013)
Oryza sativa (Rice)	Demonstrated multiplex genome editing and chromosomal-fragment deletion in stable transgenic rice plants	Xie *et al*. (2015)
Oryza sativa (Rice)	Designed CRISPR/Cas9 vector system, utilizing a plant codon-optimized Cas9 gene, for convenient and high-efficiency multiplex genome editing in rice	Xu *et al*. (2015)
Populus trichocarpa (Black cottonwood)	Four guide RNAs (gRNAs) were designed to target distinct poplar genomic sites of the phytoene desaturase gene 8 (*PtoPDS*) resulting in albino phenotypes	Fan *et al*. (2015)
Populus trichocarpa (Black cottonwood)	Two CoA ligase genes, *4CL1* and *4CL2*, associated with lignin and flavonoid biosynthesis, respectively were targeted using CRISPR/Cas9 editing	Zhou *et al*. (2015a, b)
Oryza sativa (Rice)	CRISPR/Cas9 to generate targeted double-strand breaks and to deliver an RNA repair template for homology directed repair	Butt *et al*. (2017)
Oryza sativa (Rice)	RNAi expression element is incorporated into a CRISPR/Cas9 vector, the activity and presence of the T-DNA in the transgenic plants monitored based on RNAi	Lu *et al*. (2017)
Oryza sativa	Disrupted the fatty acid desaturase 2(*OsFAD2-1*) gene	Abe *et al*.

(Rice)	which catalyzes the conversion of oleic acid to linoleic acid in rice by CRISPR/Cas9-mediated targeted mutagenesis resulting in production of rice with improved fatty acid composition	(2018)
Oryza sativa (Rice)	Inactivation of the Cs+ -permeable K+ transporter *OsHAK1* with the CRISPR-Cas system dramatically reduced Cs+ uptake by rice plants	Nieves-Cordones *et al*. (2017)
Oryza sativa (Rice)	Used CRISPR/Cas9-mediated multiplex to develop early maturing varieties of rice by targeting *Hd2*, *Hd3* and *Hd5* involved in flowering suppression	Li *et al*. (2017a, b)
Oryza sativa (Rice)	Development of new *indica* rice lines with low Cd accumulation and no transgenes by knocking out the metal transporter gene *OsNramp5* using CRISPR/Cas9 system	Tang *et al*. (2017)
Oryza sativa (Rice)	Replaced the japonica *NRT1.1B* allele with the indica allele, in just one generation, using CRISPR/Cas9 gene-editing technology	Li *et al*. (2018a, b, c, d)
Oryza sativa (Rice)	Utilized CRISPR/Cas9 technology to edit pyrabactin resistance 1 (*PYR1*)/PYR1-like (*PYL*) genes to promote rice growth and productivity	Miao *et al*. (2018)
Oryza sativa (Rice)	CRISPR/Cas9-based genome editing was used to knockout the *SaF* and *SaM* alleles of an *indica* rice line to create hybrid-compatible lines	Xie *et al*. (2017)
Oryza sativa (Rice)	Created high-amylose rice through CRISPR/Cas9-mediated editing of starch branching enzyme IIb (*SBEIIb)*	Sun *et al*. (2017)
Oryza sativa L (Rice)	Knocking out one or two of the three indica rice allele *Sc-i* copies by CRISPR/Cas9 rescues *japonica* rice allele *Sc-j* expression and male fertility	Shen *et al*. (2017)
Oryza sativa	Used CRISPR/Cas9 to introduce a loss-of-function	Zhang *et al*.

(Rice)	mutation into the *Waxy* gene in two widely cultivated elite japonica varieties	(2018a, b)
Oryza sativa (Rice)	Mutant GFP gene contained target sites in its 5_coding regions were successfully cleaved by a CAS9/sgRNA complex that, along with error-prone DNA repair, resulted in creation of functional GFP genes	Jiang *et al*. (2013)
Oryza sativa (Rice)	Improvement of rice blast resistance by engineering a CRISPR/Cas9 SSN (C-ERF922) targeting the *OsERF922* gene in rice	Wang *et al*. (2016)
Solanum lycopersicum (Tomato)	*Agrobacterium tumefaciens*-mediated CRISPR/Cas9 system transformation method was used for obtaining tomato *ALC* gene mutagenesis and replacement, in absence and presence of the homologous repair template resulting in breeding tomatoes with long shelf life	Yu *et al*. (2017)
Solanum lycopersicum (Tomato)	Created targeted mutations in phytoene desaturase (*pds*), an important gene in the carotenoid biosynthesis pathway	Parkhi *et al*. (2018)
Solanum lycopersicum (Tomato)	Targeted point mutagenesis at genomic regions specified by single-guide RNAs (sgRNAs)	Shimatani *et al*. (2017)
Solanum lycopersicum (Tomato)	To increase GABA content in tomato by deleting the autoinhibitory domain of *SlGAD2* and *SlGAD3* using CRISPR/Cas9	Nonaka *et al*. (2017)
Solanum lycopersicum (Tomato)	Used CRISPR/Cas9 system to introduce somatic mutations effectively into *SlIAA9*, gene controlling parthenocarpy	Ueta *et al*. (2017)
Solanum lycopersicum (Tomato)	Developed resistance to the powdery mildew fungal pathogen using the CRISPR/Cas9 technology	Nekrasov *et al*. (2017)

Solanum lycopersicum (Tomato)	Used CRISPR/Cas9 to target mutations to the *PROCERA* encoded *DELLA* domain of tomato to create gibberellins responsive dominant dwarf	Tomlinson *et al*. (2019)
Solanum lycopersicum (Tomato)	Promoter was inserted upstream of a gene controlling anthocyanin biosynthesis, resulting in overexpression and ectopic accumulation of pigments in tomato tissues	Cerrmak *et al*. (2015)
Citrus sinensis (Sweet orange)	Targeted genome modification in citrus using the Cas9/sgRNA system to the study of citrus gene function and for targeted genetic modification	Jia *et al*. (2017)
Panicum virgatum (Switchgrass)	Developed CRISPR/Cas9 genome editing system to target a key enzyme involved in the early steps of monolignol biosynthesis to create switchgrass knock-out mutant plants with decreased lignin content and reduced recalcitrance	Park *et al*. (2017)
Theobroma cacao (Cacao tree)	Application of genome editing technology in cacao, using Agrobacterium-mediated transient transformation to introduce CRISPR/Cas9 components into cacao leaves and cotyledon cells	Fister *et al*. (2018)
Triticum aestivum (Wheat)	Use of sgRNAs for sequence-specific CRISPR/Cas-mediated mutagenesis and gene targeting in wheat	Shan *et al*. (2014)
Triticum aestivum (Wheat)	Knock-down of *TaEDR1* by virus-induced gene silencing or RNA interference enhanced resistance to powdery mildew, indicating that *TaEDR1* negatively regulates powdery mildew resistance in wheat	Zhang *et al*. (2017)
Triticum aestivum (Wheat)	Designed two sgRNAs to target a conserved region adjacent to the coding sequence for the 33-mer in the α-gliadin genes which produced low-gluten, transgene-free wheat lines which could suppress Coeliac disease	Sanchez-Leon *et al*. (2018)

Triticum aestivum (Wheat)	Used CRISPR/Cas9 in hexaploid bread wheat to introduce targeted mutations in the three homoeoalleles that encode mildew-resistance locus (MLO) proteins	Wang *et al*. (2014)
Triticum aestivum (Wheat)	Applied CRISPR/Cas9 genome editing system in wheat protoplast to conduct the targeted editing of stress-responsive transcription factor genes	Kim *et al*. (2018)
Zea mays (Maize)	Demonstrated targeted mutagenesis in *Zea mays* using TALENs and the CRISPR/Cas system induced targeted mutations in *Z. mays* protoplasts resulting in genome modification in maize	Liang *et al*. (2014)

Table 2 CRISPR/Cas9 editing in a model plant *Arabidopsis thaliana*

Modification	**Reference**
Examined several plant generations with seven genes at 12 different target sites to determine the patterns, efficiency, specificity, and heritability of CRISPR/Cas-induced gene mutations or corrections in *Arabidopsis thaliana*	Feng *et al*. (2014)
Nuclease-induced targeted mutagenesis events in the *ADH1* and *TT4* genes of *Arabidopsis thaliana* resulting in stable inheritance of nuclease-induced targeted mutagenesis events	Fauser *et al*. (2014)
Demonstrating the efficiency of Cas9/sgRNA in causing modification of a chromosomally integrated target reporter gene	Jiang *et al*. (2014)
Co-expressed the plant codon-optimized *SpCas9* (*pcoCas9*) and a gRNA targeting the *Arabidopsis thaliana PDS3* (*PHYTOENE DESATURASE*) gene, to disrupt *PDS3* to abolish carotenoid biosynthesis and promote chlorophyll oxidation leading to a photobleached phenotype	Li *et al*. (2013)
Demonstrated that the Cas9 nuclease is able to induce heritable mutations in *Arabidopsis thaliana*	Schiml *et al*. (2014)
Site-directed mutagenesis of the Arabidopsis nuclear genome that	Hyun *et al*. (2015)

efficiently generates heritable mutations using the RNA-guided endonuclease (RGEN) derived from bacterial CRISPR/Cas9 system	
CRISPR/Cas9 technology to introduce sequence-specific deleterious point mutations at the *eIF(iso)4E* locus in *Arabidopsis thaliana* to successfully engineer complete resistance to Turnip mosaic virus (TuMV)	Pyott *et al*. (2016)
Agrobacterium tumefaciens was used for delivery of genes encoding Cas9, sgRNA and a non-functional, mutant green fluorescence protein (GFP) to *Arabidopsis thaliana*	Jiang *et al*. (2013)
Engineered CRISPR/Cas was active in creating DSBs when transiently expressed in *Arabidopsis* protoplasts and stably expressed in transgenic *Arabidopsis thaliana*	Feng *et al*. (2013)

Enhancement of Yield

Increasing the yield is a prime focus for crop improvement considering the aim of global food security. Few studies demonstrating the use of CRISPR/Cas9 for improvement of yield is described here. Flowering is governed by season and daylength in many plants and this is a prime factor that determines the suitability of a crop plant at a particular geographic location. Modification of the photoperiod response can be highly beneficial considering its potential to break the geographic specificity barrier. In a study reported by Soyk *et al*., it was demonstrated that the loss of day-length-sensitive flowering in tomato is driven by the florigen paralog and flowering repressor *SP5G* (Soyk *et al*. 2017). CRISPR/Cas9-engineered mutations in *SP5G* caused faster flowering resulting in early yield and demonstrated the power of gene editing.

The use of multiple guide RNAs for complex genome editing is a challenging objective. Cai *et al*. (2018a, b) demonstrated the use of CRISPR/Cas9 technology for targeted deletions of DNA fragments in *GmFT2a* and *GmFT5a* in soybean. Furthermore, they have demonstrated the heritability of such changes in the T2 generation with late-flowering phenotype (Cai *et al*. 2018a, b).

Rice is an important staple food in various parts of the world. Hybrid rice breeding is considered an important strategy for rice improvement. Production of a male-sterile line is highly advantageous for rice breeding. The photo- and temperature-sensitive male sterile line is required for two-line hybrid rice breeding (Barman *et al*. 2019). In a study, Zhou *et al*. (2016)

demonstrated an efficient rice thermo-sensitive genic male sterility (TGMS) cultivating system. CRISPR/Cas9 was utilized to knock out *TMS5* and develop 11 lines within a short span of one year (Zhou *et al*. 2016).

In another study, grain yield was enhanced by modifying multiple sets of regulatory genes by CRISPR/Cas9 (Li *et al*. 2016). From previous studies, it was known that the *Gn1a*, *DEP1*, *GS3* and *IPA1* controls grain yield through enhancing the grain number, panicle architecture, grain size and plant architecture, respectively. The plants mutated in the above four genes by CRISPR/Cas9 showed an enhancement of grain yield similar to those described in some previous reports. The T2 generation of the *gn1a*, *dep1*, and *gs3* mutants demonstrated increased grain number, dense and erect panicles, and larger grain size, respectively (Li *et al*. 2016).

The use of CRIPSR/Cas9 technology for improving crop yield has also been reported in tomato by the targeted editing of the *cis*-regulatory element affecting fruit size, inflorescence architecture and growth habit (Rodriguez-Leal *et al*. 2017). An increase of up to 70% in the size of tomato fruits was reported in this communication. This methodology therefore provides a foundation for dissecting the interactions between alterations in gene regulations and their effects on quantitative traits towards the ultimate goal of yield improvement.

Quality Enhancement

Ma *et al*. (2015) utilized multiple sgRNA cassettes for multiplex genome editing, resulting in the multiple, simultaneous changes in the *OsWaxy* gene, causing a fivefold reduction of amylose content in the resultant rice plants. Knocking out the *Waxy* gene towards achieving the same goal has also been reported recently by Zhang *et al*. (2018a, b). For improving the nutritional quality of wheat, low-gluten lines were developed by multiplex knockout of α-gliadin genes (Sanchez-Leon *et al*. 2018). This technology has also been used for the production of nutritionally desirable high-amylose containing rice by editing *SBEI* and *SBEIIb* through CRISPR/Cas9 technology (Sun *et al*. 2017). As well, a reduction of the anti-nutritional compound Phytic acid was achieved through the targeting of inositol phosphate kinase (*ZmIPK*) gene, a key enzyme in their biosynthetic pathway (Liang *et al*. 2014). Lawrenson *et al*. (2015) demonstrated the utility of CRISPR/Cas9 system in targeting the important agronomic trait of dormancy, by editing the ABA-inducible plasma membrane protein gene, *HvPM19* (Lawrenson *et al*. 2015).

Tomato plants producing increased levels of γ-aminobutyric acid (GABA, a nonproteinogenic amino acid with hypotensive properties) was generated employing NHEJ (Nonaka *et al*. 2017). The production of tomato fruits of different colors (purple, yellow, pink) catering to differing consumer preferences, through targeting *Anthocyanin 2*, *phytoene synthase 1* or *MYB transcription factor12* genes have also been produced through the application of CRISPR/Cas9 technology (Cermak *et al*. 2015; Filler Hayut *et al*. 2017). The amount of the bioactive compound lycopene in tomato fruits (thought to lower the incidence of cancer and cardiovascular diseases), has been increased over fivefold employing CRISPR/Cas9 technology to target carotenoid biosynthesis pathway (Li *et al*. 2018a, b, c, d). On the other hand, Tang *et al*. (2017) knocked out the metal transporter gene (*OsNramp5*) resulting in a dramatic decrease of the toxic heavy metal Cadmium concentration in the grains of *indica* rice without compromising yield (Tang *et al*. 2017).

Biotic Stresses/Disease Resistance

Targeted mutagenesis of CRISPR/Cas9 mediated deletion of several nucleotides from the promoter region of *OsSWEET11* and *OsSWEET14* modulating resistance to bacterial leaf blight was reported by Jiang *et al*. (2013). Improved resistance against bacterial blight has been achieved in rice by modifying *OsSWEET13* sugar transporter gene (Zhou *et al*. 2015a, b), targets of the pathogens' transcription activator-like affectors (TALEs), which are required for their virulence. As well, Wang *et al*. (2016) knocked out the ERF transcription factor gene (*OsERF922*) imparting enhanced resistance against the fungal pathogen responsible for rice blast disease (Wang *et al*. 2016). Recently, CRISPR/Cas9 technology has also been used to generate canker resistant citrus varieties by editing the *CsLOB1* gene (Jia *et al*. 2017). In bread wheat, simultaneous editing of three homeoalleles of the *MLO* gene conferred resistance to powdery mildew (Wang *et al*. 2014). Similarly, Zhang *et al*. (2017) reported simultaneous editing of three *TaEDR1* homeologs, enhancing resistance to the same pathogen (Zhang *et al*. 2017). As well, transgene-free tomato with enhanced powdery mildewresistance has been achieved using CRISPR/Cas9mediated editing of *SlMlo1*gene (Nekrasov *et al*. 2017), and Kumar *et al*. recently (2018) reported the generation of gene-edited barley genotypes (SpCas9-edited hvmorc1-KO barley with mutated microrchidia proteins) imparting increased resistance to fungal pathogens (Kumar *et al*. 2018).

The application of the CRISPR/Cas9 system for gene editing towards modulating virus resistance has been reported in a number of cases (Ali *et al*. 2015; Baltes *et al*. 2015; Iqbal *et al*. 2016; Ji *et al*. 2015). Ali *et al*. (2015) used this system to generate *Nicotiana bentahamiana* plants resistant against Beet curly top virus, Tomato yellow leaf curl virus and Merremia mosaic virus, while Bean yellow dwarf virus (Baltes *et al*. 2015), and BSCTV (Ji *et al*. 2015) has also been targeted. Broad-spectrum Gemini virus resistance has also been demonstrated against several begomo viruses (Zaidi *et al*. 2016). Resistance to begomo virus in cotton (Iqbal *et al*. 2016) and the production of cucumber genotypes resistant to cucumber vein yellowing virus, Zucchini yellow mosaic virus and Papaya ringspot mosaic virus cucumber has also been reported (Chandrasekaran *et al*. 2016). However, a note of caution needs to be recognized since a recent study (Mehta *et al*. 2019) aiming to engineer Gemini virus resistance in cassava plants, observed the enhanced evolution of mutated virus, resistant to CRISPR/Cas9 cleavage. Therefore, a careful assessment of this technology in relation to biosafety risks needs to be undertaken to circumvent the inadvertent effects of this technology.

Abiotic Stresses

Herbicide (bentazon and sulfonylurea) resistant rice plants were generated through *Agrobacterium*-mediated transformation and CRISPR/Cas9 technology (Xu *et al*. 2014). Similarly, Sun *et al*. (2016) generated herbicide-tolerant rice plants by mutating the branched-chain amino acid biosynthesis gene (acetolactate synthase, *ALS*) employing CRISPR/Cas9 technology (Sun *et al*. 2016). On the other hand, Li *et al*. (2016) produced glyphosate-resistant rice plants through targeting *OsESPS* gene using this technology (Li *et al*. 2016). As well, Tian *et al*. (2018) recently reported the production of herbicide-resistant watermelon varieties through the targeted mutation of the *ALS* gene employing CRISPR-Cas9 technology (Tian *et al*. 2018). Recently, editing the low-temperature sensitivity regulating transcription factor *TIFY1* has been demonstrated (Huang *et al*. 2017), which can shed light on the regulation of low-temperature sensitivity and adaptation.

Drought Tolerance

Drought-tolerant maize variants have been generated by editing the weak, endogenous promoter of *AGROS8*, the negative regulator of ethylene response, using CRISPR/Cas9 technology (Shi *et al*. 2017). On the other hand, Wang *et al*. (2017) reported the MAPKs edited tomato plants being more sensitive to drought when compared to the non-edited controls (Wang

et al. 2017). However, they screened just two transgenic line, and it is entirely possible that that the production and screening of additional lines could lead to the identification of genotypes with enhanced resistance to drought, since most of the mutations/changes produced, by nature, are detrimental. Similarly, Li *et al*. (2019a, b) have also reported the generation of tomato plants with reduced tolerance to drought due CRISPR/Cas9 mediated mutagenesis of the *NPR1* (non-expressor of pathogenesis-related gene 1) (Li *et al*. 2019a, b). However, *NPR1* is a master regulator of plant defense response, but not much information is available on its role in modulating abiotic stresses, although another pathogenesis-related protein (PR10) is known to be involved in imparting drought- and salt-tolerance (Srivastava *et al*. 2006). Several recent publications (Chen *et al*. 2019; Paixao et al. 2019) have reported the enhancement of drought and salt tolerance employing CRISPR/Cas9 technology. Paixao *et a*l. (2019) fused the dCAS9with the gene activator histone acetyltransferase (HAT) targeting the Abscisic acid-responsive element binding protein 1 (AREB1), a key regulator of drought stress response in plants (Paixao *et al*. 2019). The resultant *Arabidopsis* plants exhibited improved survival rate after the imposition of drought stress. In another such example, Chen *et al*. (2019) established the editing of transcription repressors DPA4 and SOD7 enhancing abiotic salt and drought tolerance along with an increase in seed size through the regulation of inflorescence architecture in *Arabidopsis*.

In a recent study, Bhowmik *et al*. (2018) incorporated the use of CRSPR-Cas9 technology with wheat microspore culture to demonstrate the possibility of exploiting haploid breeding technology and targeted gene editing (Bhowmik *et al*. 2018). They were able to transform both endogenous and exogenous (reporter) genes and regenerate microspore-derived plants using this technology. Similarly, Hensel *et al*. (2018) reported the regeneration of haploids from pollen grains of primary transformants, demonstrating the combined utility of haploid technology and gene editing (Hensel *et a*l. 2018). Lu and Zhu (2017) achieved enhanced nitrogen use efficiency by targeting *NTR1, 1B* genes through targeted base editing, while Zong *et al*. (2017) modulated senescence and cell death by targeting *OsCDC48* employing the same technology (Lu and Zhu 2017; Zong *et al*. 2017). The shelf-life of tomato fruits has also been increased through the targeted mutagenesis and gene replacement of the *ALC* gene in tomato (Yu *et al*. 2017).

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SMART SOIL FERTILITY DETECTION USING IOT AND MACHINE LEARNING

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Abstract

Soil fertility is a critical factor in ensuring sustainable agricultural productivity. Traditional methods of soil analysis are often time-consuming, labor-intensive, and lack real-time feedback. This study explores the integration of Internet of Things (IoT) and Machine Learning (ML) technologies to develop a smart soil fertility detection system that enables continuous, accurate, and cost-effective monitoring of soil health. The proposed system utilizes a network of IoT-based sensors to collect real-time data on key soil parameters such as moisture, pH, temperature, electrical conductivity, and nutrient levels (NPK). The collected data is transmitted to a cloud-based platform, where advanced ML algorithms analyze and classify soil fertility status, predict nutrient deficiencies, and provide tailored recommendations for site-specific nutrient management. This approach enhances decision-making for farmers, optimizes fertilizer usage,

and promotes sustainable farming practices. The implementation of smart soil monitoring can significantly improve crop yields, reduce environmental impact, and support precision agriculture initiatives.

Introduction

Soil fertility is the foundation of agricultural productivity, governing plant health, yield quality, and long-term sustainability of farming systems. Traditionally, soil nutrient analysis has relied on laboratory testing, which is accurate but time-consuming, labor-intensive, and often inaccessible to smallholder farmers. As a result, fertilizer application is frequently based on guesswork, leading to overuse, underuse, or imbalanced nutrient supply. This not only reduces crop yields but also degrades soil health and contributes to environmental pollution. Recent advances in Internet of Things (IoT) technology and machine learning have opened new pathways for real-time, precise, and scalable soil fertility monitoring. IoT-enabled sensors can continuously measure critical soil parameters—such as moisture, pH, temperature, and nutrient levels (NPK) and transmit this information to cloud-based platforms. Machine learning algorithms analyze these data streams to identify nutrient deficiencies, predict soil fertility trends, and provide tailored recommendations for fertilizer management. By integrating sensor networks with predictive analytics, farmers gain actionable insights at their fingertips, enabling data-driven decisions that enhance productivity, optimize input use, and reduce environmental impacts. This convergence of IoT and artificial intelligence represents a significant step toward precision agriculture, where every input is applied at the right place, in the right amount, and at the right time.

Why Soil Fertility Detection Matters

Crop yields are strongly influenced by soil nutrient composition, particularly nitrogen (N), phosphorus (P), and potassium (K). Inaccurate knowledge of soil status leads to inappropriate nutrient application, degrading crops and lowering production.

Key reasons for monitoring soil fertility:

- Identify nutrient deficiencies early.
- Determine exact fertilizer requirements.
- Improve productivity and reduce input costs.
- Minimize environmental impact from fertilizer overuse.

- Traditional soil testing methods, while accurate, are time-consuming, labor-intensive, and require laboratory expertise. The integration of IoT and machine learning provides a faster, scalable alternative.

IoT in Soil Monitoring

IoT-based systems deploy field sensors to collect real-time data on:

- Soil moisture
- pH and electrical conductivity
- Temperature and humidity
- Nutrient content (N, P, K)

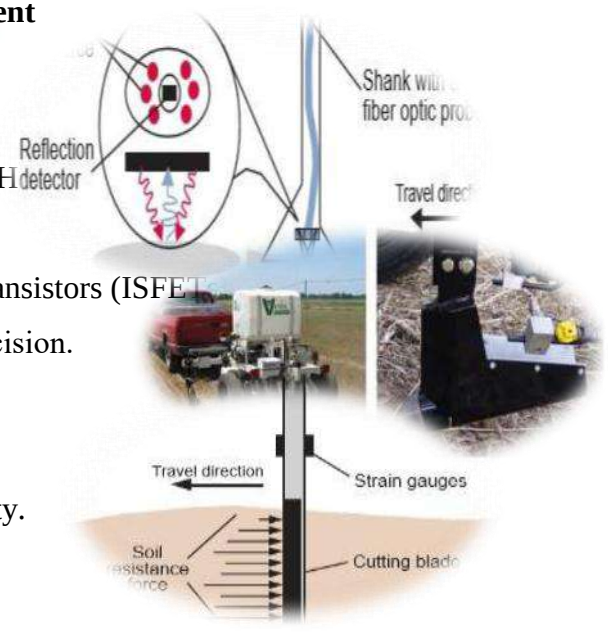
These sensors communicate with a central network (cloud-based platforms such as ThingSpeak), enabling farmers to monitor conditions remotely via mobile apps. Prompt alerts allow immediate corrective actions, ensuring crops receive optimum nutrition.

Machine Learning for Smart Agriculture

Machine learning algorithms analyze data gathered by IoT sensors to:

- Detect nutrient deficiencies.
- Correlate soil conditions with yield performance.
- Continuously improve prediction accuracy using historical datasets.
- Predictive modeling enables farmers to forecast soil fertility changes and determine the optimal timing and amount of fertilizer application, minimizing waste and cost.

Sensor Technologies for Precision Soil Nutrient Management



1. Optical and Radiometric Sensors

Measure soil reflectance and color.

Hyperspectral analysis correlates with soil carbon, nitrate, and pH

2. Electrochemical Sensors

Use ion-selective electrodes or ion-selective field effect transistors (ISFET)

Detect specific nutrient ions such as H^+, K^+, NO_3^- with high precision.

3. Mechanical Sensors

Assess soil compaction using vertical cone penetrometers.

Automated prototypes improve speed and reduce variability.

4. Soil Moisture Sensors

Devices such as FC-28 calculate soil water content.

Adequate soil moisture is critical for nutrient absorption.

5. Temperature and Humidity Sensors

DHT11 sensors monitor microclimate conditions.

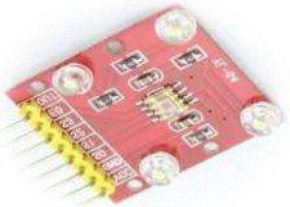
Ideal humidity: 20–80%; temperature: 0–50 °C.

6. Colour Sensors

AS9100 chips analyze soil color intensity to detect nutrient-related changes.

7. Rain Sensors

Pause irrigation automatically during rainfall, preventing overwatering.



8. Microcontrollers (NodeMCU ESP8266)

Act as a central hub with built-in Wi-Fi for cloud connectivity.

The NPK Sensor: A Game-Changer

- The fiber optic-based NPK sensor measures nitrogen, phosphorus, and potassium simultaneously using a colorimetric principle.
- Light intensity variations indicate nutrient levels.
- Data is compared against stored threshold values to identify deficiencies.
- Fast response time (<10 seconds), durable construction, and suitability for long-term soil embedding make it practical for field use.

Example output:

Nitrogen low → Additional N required.

Phosphorus adequate → No supplementation.

Potassium high → Avoid K fertilizer to reduce waste.

Benefits for Farmers

- ✓ No need for manual sampling or laboratory tests
- ✓ Instant, real-time reports on mobile devices
- ✓ Data-driven recommendations optimize fertilizer use
- ✓ Reduced input costs and environmental impact
- ✓ Improved crop yields through targeted nutrient management

Challenges and Limitations

- ✓ Sensors must be calibrated to match crop-specific nutrient responses.
- ✓ Lack of technical awareness and infrastructure in rural areas.

- ✓ Farmers may be hesitant to adopt emerging IoT solutions due to perceived complexity or cost.

Recent Advances in Machine Learning for Soil Testing

- ✓ An Ensemble Learning Modeling (ELM) approach has shown exceptional performance in predicting Soil Organic Carbon (SOC) and Total Nitrogen (TN) using Near Infrared (NIR) spectroscopy:
- ✓ SOC prediction accuracy: $R^2 = 0.96$
- ✓ TN prediction accuracy: $R^2 = 0.94$
- ✓ This surpasses traditional Partial Least Squares (PLS) and Back-Propagation Neural Networks (BPNN), demonstrating the robustness of ensemble methods for soil fertility assessment.

Conclusion

The integration of IoT sensors and machine learning models is transforming agriculture from reactive to predictive management. Farmers can now monitor soil conditions continuously, receive actionable recommendations instantly, and optimize resource use without guesswork. This data-driven approach to soil fertility detection holds the key to higher productivity, lower costs, and sustainable farming for the future.

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BIOCONTROL OF PLANT PATHOGENIC NEMATODES BY MICRO- ORGANISMS

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Abstract

Plant-parasitic nematodes are among the most destructive agricultural pests, causing significant yield losses worldwide by predisposing plants to secondary infections and disrupting the nutrient cycle. Conventional management strategies rely heavily on chemical nematicides, which pose risks to human health and environment. In recent years, microbial biocontrol has emerged as a sustainable and eco friendly alternative for nematode management.

Introduction:

Plant parasitic nematodes (PPN) are naked to human eyes but have a drastic and terrific impact on global agriculture. An estimated $157 billion is lost in yield each year as a result of these pests with over 4,100 identified species affecting essential crops such as rice, tomato, soybean, and sugarcane. Root-knot nematodes (***Meloidogyne*** spp.), dagger nematodes (***Xiphinema*** spp.), lesion nematodes (***Pratylenchus*** spp.), and cyst nematodes (***Heterodera*** and ***Globodera*** spp.) are few examples of these pests which adversely affect the plant by attacking roots and blocking the uptake of nutrients and water.

Farmers around the globe, especially in developing agricultural economies, face the brunt of these infestations, with limited access to safe and sustainable control methods. As climate change further alters soil and plant dynamics, the threat posed by these pests is expected to increase, demanding urgent and effective solutions that go beyond chemical quick-fixes.

A New alternative: Since a long time synthetic nematicides have been used to control these pests. But their continued use leads to other problems like groundwater contamination. As a more

sustainable method BCA- Biocontrol agents are being used, which are bacteria and fungi that naturally suppress nematodes in the rhizosphere. In order to directly or indirectly combat PPN's, BCA's have evolved sophisticated and intricate mechanisms.

Mechanisms Used:

Direct Antagonism:

This is a hands-on approach where microbes physically or chemically target nematodes.

Predation and Parasitism: Some fungi, like **Arthrobotrys oligospora**, are natural nematode hunters. They form specialized trapping structures—such as sticky nets or constricting rings—that physically capture nematodes. Once trapped, the fungus invades and digests the nematode, using it as a nutrient source.

Toxin Production: Certain bacteria such as Bacillus thuringiensis (Bt) produce Cry proteins—crystalline toxins that, when ingested by nematodes, damage their digestive system and eventually kill them. This same mechanism is also what makes Bt a popular choice in insect biocontrol.

Lytic Enzymes: Some microbes secrete enzymes like chitinases, proteases, and lipases which break down the structural barriers of nematode eggs or cuticles. These enzymes essentially dissolve the protective outer layers, rendering the nematodes vulnerable or killing them before they even reach maturity.

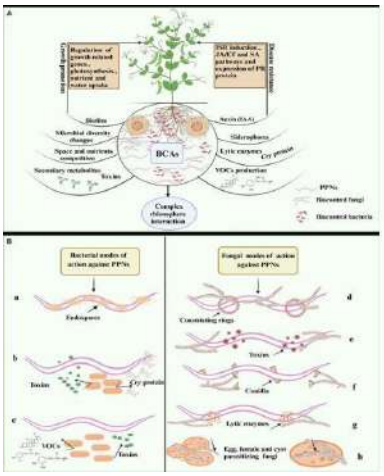
Indirect Antagonism

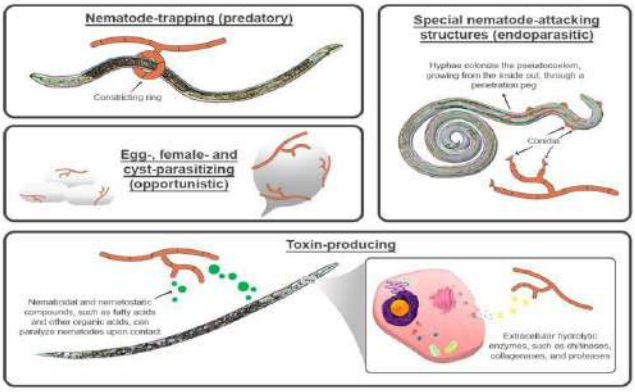
Rather than attacking nematodes directly, some BCAs work by making the plant itself more resistant or by altering the environment in ways that nematodes can't thrive.

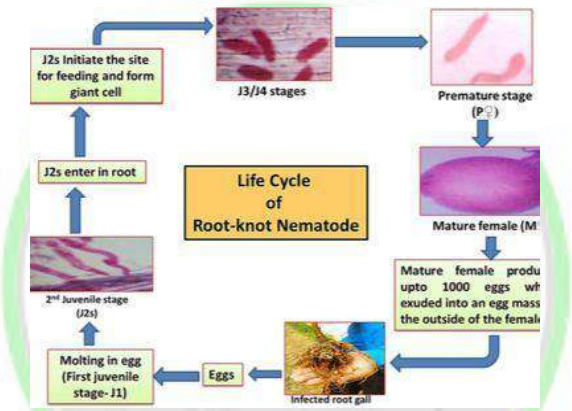
Induced Systemic Resistance (ISR): Certain Plant Growth-Promoting Rhizobacteria (PGPR) such as ***Pseudomonas fluorescens*** act like a vaccine for plants. They stimulate the plant's own immune system, priming it to defend itself more effectively against nematode invasion. This internal alert system allows the plant to react faster and stronger if a nematode tries to attack.

Competition for Resources:

Beneficial microbes often outcompete nematodes in the rhizosphere (the soil zone near plant roots) by claiming the available nutrients and space. When the "good" microbes dominate root surfaces, nematodes are unable to establish a foothold, reducing their population naturally without direct confrontation.







Successful Microbial Biocontrol Examples:

Bacillus atrophaeus GBSC56: This strain has been shown to significantly reduce root-knot nematode infection in tomatoes. It works by a combination of enzyme production and competition in the root zone.

Pseudomonas fluorescens F113: Known for its multifaceted capabilities, this strain interferes with the hatchability of potato cyst nematodes and impairs juvenile mobility, thereby disrupting their life cycle before they can harm the plant.

Serratia plymuthica: This bacterium is known for producing several bioactive compounds that can suppress nematode development, along with benefiting plant growth through nitrogen fixation and phytohormone production.

Paenibacillus polymyxa: A powerful biocontrol agent that not only reduces nematode infestation but also enhances plant vigour by producing antibiotics, growth hormones, and enzymes that support overall plant health.

Challenges and Limitations:

- Inconsistent Field Performance: One of the biggest setbacks in applying BCAs on a large scale is their unpredictable effectiveness in different environments. What works brilliantly in one field might underperform in another due to factors like soil pH, moisture content, temperature, or the presence of native soil microbes that may outcompete or suppress the introduced BCA.
- Formulation and Shelf Life: Unlike synthetic chemicals, microbial formulations are living products. Developing stable, easy-to-use formulations that can survive storage, transport, and field application is a constant technical challenge. Farmers need something reliable that won't lose its efficacy by the time it's sprayed onto their crops.
- Regulatory Barriers: Biocontrol products often face complex and lengthy approval processes. Regulators must ensure these microbial agents are safe—not just for crops, but also for non-target organisms, humans, and the environment. While this scrutiny is essential, it can delay the commer availability of potentially game-changing solutions.
- Awareness and Adoption: In many parts of the world, especially in developing nations, there is limited awareness about microbial biocontrol methods. Farmers may be hesitant to switch from familiar chemical treatments to biologically based ones, fearing poor results or lacking the technical know-how for proper application.

Despite these obstacles, the future remains bright. With innovations in metagenomics, biotechnology, and precision agriculture, many of these challenges are already being addressed.

Conclusion

As the global demand for food continues to rise, so does the need for sustainable agricultural practices. Biocontrol of plant parasitic nematodes using microorganisms offers an ecofriendly, effective, and scientifically based alternative to chemical nematicides. Biocontrol strategies offer particular promise for small-scale farmers who cannot afford expensive chemical treatments but can benefit from cost-effective, eco-friendly methods tailored to their local soil and crop conditions. When used wisely and backed by modern biotechnology, BCAs can provide long-term protection while reducing the environmental toll of conventional practices.

To truly harness the potential of biocontrol agents, a collaborative effort is needed—between researchers, agricultural extension workers, farmers, and policymakers. Investment in

field trials, education on application techniques, and support for regulatory approvals will be key to mainstreaming these microbial allies.

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Bioagents for management of plant parasitic nematodes- Agriculture

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MANAGEMENT OF GUAVA ROOT KNOT NEMATODE (*Meloidogyne enterolobii*) THROUGH CULTURAL PRACTICES

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Introduction

Guava (*Psidium guajava*), often referred to as the "poor man's fruit," holds significant commercial value in India and ranks as the fourth most important fruit crop after mango, banana, and citrus. A member of the Myrtaceae family, guava cultivation faces major threats from the root-knot nematode *Meloidogyne enterolobii*, which can lead to yield losses exceeding 65%. Infected plants typically display yellowing leaves, wilting, and restricted growth above ground, while the roots often show extensive gall formation.Due to the harmful environmental effects of synthetic pesticides, researchers are increasingly focusing on alternative strategies such as biological control, crop rotation, cultural methods, and developing resistant plant varieties. Among these, cultural practices and biological approaches are considered more eco-friendly, as they do not leave toxic residues in the soil. Several cultural management techniques are currently being adopted to mitigate the impact of root-knot nematodes in guava cultivation.

Selection of nematode free planting materials

In plants propagated through vegetative methods, nematodes can be effectively eliminated by choosing vegetative parts from healthy, nematode-free plants. For instance, selecting nematode-free planting material helps prevent the spread of the golden nematode in potato, as well as burrowing nematode, spiral nematode and lesion nematode in banana and root knot nematode in guava. Similarly, using nematode-free seeds can control the wheat seed gall nematode and the rice white tip nematodes.

Adjusting the time of planting

The life cycle of nematodes is influenced by climatic conditions. By adjusting the planting time, it is possible to reduce or avoid damage caused by nematodes. In certain situations, planting crops during the winter when soil temperatures are low can be beneficial, as nematodes are less active in cooler conditions. For example, early planted potatoes and sugar beets grown during the cold season often escape damage from cyst nematodes, since the low temperatures prevent the nematodes from becoming active enough to harm the crops.

Fallowing

Leaving the field uncultivated, especially after ploughing, exposes nematodes to sunlight and causes them to die from lack of food, as no host plants are available.

Deep summer ploughing

At the beginning of summer, infested fields are ploughed using a disc plough and left exposed to the intense sunlight, which increases soil temperature and helps eliminate nematodes. For establishing small nursery beds of vegetables like tomato and brinjal, the beds can be prepared during summer and covered with polythene sheets. This process raises the soil temperature by 5 to 10°C, effectively killing nematodes present in the seed bed. Soil solarization using polythene sheets is a highly effective technique for producing nematode-free seedlings.

Manuring

Growing green manure crops and applying large quantities of farmyard manure, neem and castor oil cakes, press mud, and poultry manure help improve soil health. These organic amendments promote the growth of predatory nematodes like *Mononchus* species and other beneficial microorganisms that naturally suppress harmful plant parasitic nematodes in the field.

Flooding

Flooding can be used as a control method in areas with abundant water supply.When the soil is kept submerged, it creates anaerobic conditions that suffocate and kill nematodes. Additionally, harmful compounds like hydrogen sulfide and ammonia are produced under flooded conditions, which are toxic to nematodes and contribute to their elimination.

Trap cropping

In this method, two crops are cultivated in the same field, with one being highly susceptible to nematodes. The nematodes target the susceptible crop, which is intentionally planted first. By carefully timing its removal and destruction such as burning it before the

nematodes complete their life cycle the main crop can be protected from nematode damage. For example, cowpea, which is highly vulnerable to root-knot nematodes, can be grown initially and then destroyed before the nematodes mature, helping safeguard the following crop.

Antagonistic crops

Certain plants, such as mustard, marigold, and neem, release chemicals or alkaloids through their roots that repel or suppress plant-parasitic nematodes. In marigold (*Tagetes spp.*), compounds like α-terthinyl and bithinyl are found throughout the plant, from roots to shoots, and these chemicals are toxic to nematodes. Mustard contains allyl isothiocyanate, while pangola grass produces pyrocatechol, both of which are effective in killing nematodes. These nematode repellent plants can be grown alongside the main crop or used in crop rotation to help manage nematode populations.

Removal and destruction of infected plants

Early identification and removal of infested plants help limit the spread of nematodes. After harvesting, the stubble from infected plants should be cleared from the field. For example, in tobacco cultivation, roots left in the soil after harvest can serve as a source of nematode infestation for the next crop. Similarly, the nematode *Ditylenchus angustus* survives in the leftover stubble following rice harvest. To prevent this, such stubbles must be removed and destroyed, and the soil should be ploughed to expose and reduce nematode population.

Nematodes are obligate endoparasite that cause a devastating effect to the plant, which it affects. Chemicals are a threat to environment, since it leaves residual effect in the soil. Thus, cultural methods are cost effective and is easier to control nematode than other methods.

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A REVIEW STUDY ON GROUNDWATER QUALITY ASSESSMENT USINGRS & GIS TECHNIQUES

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Abstract

The explorative analysis of the project is to address the quality of groundwater because groundwater holds cultural and spiritual significance in many societies, and it is a hidden but powerful force beneath our feet. This not only allows detecting the issues affecting water quality but also enables developing specific approaches for the sustainable management and protection of groundwater. The evaluation includes physico-chemical analysis data of the groundwater samples collected at predetermined locations forming the attribute database for the study, based on which, spatial distribution maps of major water quality parameters are prepared using the curve fitting method in Arc View GIS software. The grids are thoroughly dispersed, and groundwater samples have been collected from various sources, including open wells, hand pumps, and bore wells, in each grid to assess water quality. Overall, through GIS mapping and conclusive water quality assessment, the study provides a significant input into the field of environmental science in terms of enhancing water sustainability practices.

Keywords: Groundwater, Water Quality Index, RS and GIS, Drinking and spatial variation

Introduction:

"Beneath our feet flows the lifeblood of the Earth- Groundwater"

Groundwater is one of the most vital natural resources on Earth, playing a critical role in

sustaining life. The quality of groundwater refers to the chemical, physical, and biological characteristics of groundwater that determine its suitability for various uses such as drinking, irrigation, and industrial processes. It is influenced by natural factors like soil composition, rock minerals, and rainfall, as well as human activities such as agriculture, industrial waste disposal, and sewage discharge. Groundwater contamination is now one of the most pressing global health issues, causing many illnesses and deaths. This however is most pronounced in India, where the rapid growth of industries, urbanization, and population have accelerated the release of effluents and pollutants into the environment. Groundwater safety therefore requires that its constituents such as physical and chemical entities fall within set limits for the particular use, to avoid offending effects on health. Likewise, this research is all about testing the groundwater parameters such as hardness, chloride, calcium. Total dissolved solids, pH levels and mapping those values using GIS software for accurate plotting which are the keys to be known for the purpose of purifying it in future.

The most effective means of monitoring the groundwater quality is through the use of Geographic Information System (GIS) technology aided by the IDW interpolation method. The approach has been reported to be capable of efficiently processing very big amounts of data, facilitating the creation of spatial distribution maps and projections that allow the identification of trends, correlations and sources of pollution. In thisway it is a low-cost and time-saving method for analyzing water resources. The goal is to leverage GIS interpolation techniques to evaluate the groundwater's fitness for human consumption, addressing the urgent need for comprehensive methods to safeguard our water supplies.

Sample Collection and analysis:

In order to conduct a comprehensive analysis of groundwater properties, the samples were gathered during the winter season. A variety of sources, including hand pumps, bore wells inside designated grid regions, and open wells, were used to gather these samples. Each collected groundwater sample underwent a thorough analysis to evaluate several physicochemical parameters. A total of seven ground water parameters were analyzed in the laboratory. Parameters such as hydrogen ion concentration (pH), Total Dissolved Solids (TDS), Total Hardness (TH), Carbonates (CO_3^-) and Chloride (Cl^-), Electrical Conductivity (EC), Calcium (Ca^{2+}) were analyzed.

Carbonates

Carbonates are chemical compounds that contain the carbonate ion. They are salts of carbonic acid (H_2CO_3) and are commonly found in minerals, rocks, and biological systems. Carbonates are important in geology, environmental science, and industry. The following methods are commonly used in determination of carbonates.

1. Geophysical Methods
2. Geological and Hydrogeological Methods
3. Remote Sensing and GIS Techniques
4. Traditional and Empirical Methods
5. Drilling and Test Boring

Lab analysis for presence of carbonates in groundwater:

The lab analysis of carbonates in groundwater involves quantitative testing of carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ions, typically expressed in mg/L as $CaCO_3$. This is crucial for evaluating alkalinity, water hardness, and suitability for drinking, irrigation, or industrial use.

Reagents:

0.02 N Sulphuric acid (H_2SO_4) or Hydrochloric acid (HCl)

Phenolphthalein indicator (pH ~8.3)

Methyl orange indicator (pH ~4.5)

Based on A and B values, the following rules are made

Condition	*Alkalinity Type*
A = 0	Only bicarbonate (HCO_3^-) present
A = B	Only carbonate (CO_3^{2-}) present
A < B	Both carbonate and bicarbonate
2A > B	Presence of hydroxide

Chloride:

1. Mohr's Method (Argentometric Titration)

Principle:

Chloride ions in the sample react with silver nitrate ($AgNO_3$) to form a white precipitate of silver chloride (AgCl). The endpoint is detected using potassium chromate (K_2CrO_4) as an indicator. After all chloride is precipitated, excess Ag^+ reacts with chromate to form a reddish-brown silver chromate (Ag_2CrO_4).

Reaction:

$Ag^+ + Cl^- \rightarrow AgCl$ (white ppt.)

$2Ag^+ + CrO_4^{2-} \rightarrow Ag_2CrO_4$ (reddish brown ppt.)

2. Mercuri metric Method (Volhard's Method – back titration)

Principle

Chloride is reacted with a known excess of mercury (II) nitrate, forming a stable complex. The excess is back-titrated with thiocyanate solution using ferric ammonium sulfate as indicator.

Reaction

$2Cl^- + Hg(NO_3)_2 \rightarrow HgCl_2 + 2NO_3^-$

It is used when:Mohr's method is not suitable (e.g., colored or turbid samples)

3. Ion Chromatography

Principle:

The ions including chloride are separated based on their interaction with a resin column and detected (usually by conductivity).

The special features of this method are given as below.

It gives a high accuracy.

It can measure multiple ions simultaneously (NO_3^-, SO_4^{2-}, Cl^-, etc.)

4. Spectrophotometric Methods

Chloride reacts with mercury (II) thiocyanate and ferric iron to produce a colored complex. The intensity of color (measured at specific wavelengths) correlates with chloride concentration. The instrument used for this purpose is UV-Visible Spectrophotometer.

5. Potentiometric Titration

The same reaction as Mohr's method, but the endpoint is detected using a silver electrode rather than visual color change. It is useful for colored or turbid Test.

Strips / Field Kits

The simple chloride test strips are available for semi-quantitative field testing. It is not precise but useful for initial surveys. The various types of water quality index (WQI) commonly used are given in **Table. 1.**

Table 1: Various parameters used for Water Quality Index

S. No	Water Quality Index	Symbol	Formula	Proposed by
1	Sodium Absorption Ratio	SAR	$SAR = \frac{Na^+}{\sqrt{\frac{(Ca^{2+} + Mg^{2+})}{2}}}$	Richards (1954)
2	Kelly's Ratio	KR	$KR = \frac{Na^+}{Ca^{2+} + Mg^{2+}}$	Kelley (1963)
3	Permeability Index	PI	$PI = \frac{Na^+ + \sqrt{HCO_3^-}}{Ca^{2+} + Mg^{2+} + Na^+} \times 100$	Doneen (1964)
4	Soluble Sodium Percentage	SSP	$SSP = \frac{Na^+ + K^+}{Ca^{2+} + Mg^{2+} + Na^+ + K^+} \times 100$	Todd (1980)
5	Residual Sodium Carbonate	RSC	$RSC = (CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$	Gupta and Gupta (1987)
6	Residual Sodium Bicarbonate	RSBC	$RSBC = HCO_3^- - Ca^{2+}$	Gupta and Gupta (1987)

Electrical Conductivity (EC):

It refers to the ability of a material to conduct electric current. It's typically measured in Siemens per metre (S/m). Materials with high electrical conductivity, like copper and silver, are often used in electrical wiring and circuits. There are four methods commonly used in measurement of EC.

1.Four-probe method: Four probes contact the material; outer probes apply current, inner probes measure voltage, enabling accurate conductivity calculation by eliminating contact resistance.

2. Two-probe method: It uses two probes for current and voltage measurement but less accurate due to contact resistance.

3. *Inductive (eddy current) method:* Non-contact method using coils to induce currents and measure impedance changes, useful for metals and solutions.

4. Electromagnetic induction method: It is used in liquids, measures conductivity without direct electrode contact, beneficial for corrosive or concentrated samples.

Measurement requires sample preparation, applying current, measuring voltage, and calculating conductivity. The temperature and sample thickness affect accuracy, so calibration and compensation are important. This property is critical in material characterization, quality control, and water quality monitoring.

pH:

The pH scale ranges from 0 to 14, with 7 being neutral. Values below 7 indicate acidity, while values above 7 indicate alkalinity (basicity). Most groundwater locations in the research

region had pH values between 7.15 and 7.66, which is within the acceptable limit for drinking water quality. However, in some areas like Vin Nagar have reported pale or sediment-filled water, prompting them to boil the water before consumption.

Total Dissolved Solids:

Total Dissolved Solids (TDS) measurement is a crucial aspect of groundwater quality assessment. It indicates the concentration of all organic and inorganic materials dissolved in water.TDS can be analyzed by gravimetric and conductivity method. The calculation of TDS is given as below.

TDS (mg/L) = (Weight of residue (mg) / Volume of water sample (L))

Based of the TDS values, they are classified into five groups.

Excellent : Less than 300 ppm.

Good : 300-600 ppm.

Fair : 600-900 ppm.

Poor : 900-1200 ppm.

Unacceptable : Above 1200 ppm.

The various types of water quality index (WQI) commonly used are given in **Table. 2.**

Table 2: Qualitative classification of WQI

Water Quality Index	Description
0-50	EXCELLENT
51-100	GOOD
101-200	POOR
201-300	VERY POOR
>300	UNFIT FOR DRINKING(UFD)

Calcium

There are several methods for determining calcium levels in groundwater, which are crucial for assessing its quality.

1. EDTA Titrimetric method
2. Atomic Absorption Spectrometric (AAS) method
3. Permanganate Titration method
4. Spectrophotometric method
5. Calcium ion meter

This is a commonly used and relatively simple method for determining calcium and magnesium in water samples.

It involves titrating the water sample with a standard solution of Ethylene Diamine Tetra acetic Acid (EDTA), which forms a stable complex with calcium ions. A suitable indicator (such as murexide) is used, which changes color (typically from pink to purple) at the endpoint when all the calcium has reacted with EDTA. The volume of EDTA consumed is used to calculate the calcium concentration in the groundwater.

Result

From the findings and analysis of the given area, this study concludes that the use of the GIS technology to map and analyze the chemical parameters can effectively contribute to improving the sustainability of the groundwater resources. Some of the major outcomes include the distribution of the groundwater quality within and outside the acceptable parameters of drinking water. The study makes a significant contribution to the field of environmental science by using GIS mapping to provide not only a detailed understanding of the spatial distribution of groundwater quality, but also insightful information for the sustainable management and protection of groundwater resources. In order to replenish ground water, state government and non-government organization (NGO) should support to turn excavated wells and abandoned borewells into artificial recharge structures and rainwater harvesting structures.

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FISHING IN RIVER WITH AN I DON'T CARE ATTITUDE

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Introduction

River plays an important role in the life and living of people since ancient times for transport, business, agriculture, religious aspect, drinking and daily lively hood etc. These fisheries play a vital role in providing food, income, and livelihoods, and also contribute to biodiversity and cultural heritage. However, riverine fisheries face numerous challenges such as overfishing, habitat degradation, and pollution. The social and economic dimensions of destructive fishing activities in river Kamlang, Lohit, Bereng, Teang, Tengapani, Jenthu, Buri Dihing of Namsai, Lohit and Anjaw district of Arunachal Pradesh are to be evaluated and the extent of occurrence of these activities, the social and economic factors that explain the continued existence of destructive fishing techniques, and the measures to deter the destructive fishing practices in the area to be taken care along with the effect on flora and fauna of these riverine ecosystems are alarming.

Several fish species of Cyprinidae family like *Bangana* sp., *Barilius* sp., *Cirrhinus* sp., *Crossocheilus* sp., *Cyprinion* sp., *Danio* sp., *Garra* sp., *Labeo* sp., *Pethia* sp., *Tor* sp. (Pa mon, Pa Khaam taen, Pa Kham, Pa Pon, Pa Khum, Pa mon, Pa lai, Pa neng respectively); Cobitidae family- locally known as Pa khee ; Perciformes order- *Badius, Channa, Glossogobius, Nandus* etc. (locally- Pa tang, Pa khontok, Pa khee see, Pa Mau respectively) ; other than these *Mystus, Clarius, Tetraodon, Xenentodon* etc. (Locally- Pa nook moon/ Pa nook, Pa magur, Pa pong, Pa teang respectively) are found in the different rivers on Namsai district, few of the fishes genus have been reflected in this literature. Several detailed studies are to be made on the faunal diversity of the above said rivers.

The indigenous elderly fishermen were more conscious about the destruction caused by these methods to the fishing environment and raised their concerns and frustrations as and when required. Those who are involved in destructive fishing practices in recent times are only concerned with immediate short-term gains at the expense of sustainability of the fisheries resources. A number of reasons have been identified and destructive fishing activities are a problem not only in Namsai, Lohit, Anjaw and also in Arunachal Pradesh but also throughout India both in Inland and Marine fisheries.

1. **Population:** Rapid population growth and urbanization experienced in the district have led to increased pressure on traditional fishery resources live river, marshy land, canals, paddy fields etc. In addition, destructive practices have resulted in the degradation of large areas of formerly productive riverine ecosystems.
2. **Poisoning:** These include the use of fishing poisons that is an ancient fishing method which is effective in rock pools and small, semi-enclosed areas. Traditionally, extracts from the bark or roots of a number of local plants are prepared and poured into the water. The suffocating effects eventually result in the fish floating belly-up on the surface, where they are collected. Because poisons are indiscriminate, and many other benthic organisms may be severely damaged. Often these organisms and small fish, which are not desired, are much more vulnerable to the effects of poisons than the target fish.
3. **No mesh sized regulations:** The use of small mesh-size nets is also widespread due to its perceived effectiveness in catching juvenile fish. However, despite its use being illegal, the existing laws are not effectively enforced and to be controlled locally at village level.

4. **Disturbed breeding ground**: Majority of cold water fishes migrate upstream for breeding in the month of July to September (*Tor tor*, *Tor putitora*, locally known as Pa neng) and the juveniles are found in shoals in up-streams with relatively warmer temperature profile. Such destructive fishing methods destroy the breeding grounds and the juvenile feeding cum rearing area also, which further reflect in future fish population. In comparison to other fishes the fecundity of mahseer (Pa neng) is quite low, so destruction in habitat, catch in premature stage causes less number of fishes to be matured for breeding.
5. **Irrational fishing practices**: Dynamite and electrical fishing, although illegal in society but are still used and cause widespread physical damage as well as removing or killing immature fish, brooder fish and other species of no commercial value.
6. **Seasonal ban**: Violation in 'no fishing season' causes several negative impacts on fish population in natural ecosystem, simply because it helps in the conservation and better management of fish resources. The main objective of this 'seasonal' ban during monsoon on fishing is to protect fish wealth because the riverine fishes are natural breeder while commercially important species breed in hatcheries, so if they are caught in mature stage, juvenile or fingerling stage or their migration is restricted or the habitats are destroyed ultimately resulting to fish population in coming years.
7. **Age of the fisherman**: Age of a fisherman is a significant factor in choice of a fishing gear. There was evidence that the youth dominated the use of dynamites and electrical appliances. These are gears that require a lot of energy and the elderly fishermen definitely avoid them. On the other hand majority of the elderly fishermen concentrated on use of basket traps which they weaved by themselves making it cheap to acquire and require less fishing effort.
8. **Low educational levels and lack of alternative livelihoods**: Most dropped out of school to join fishing to start earning income and ended up using destructive fishing gears. Such fishermen stick to these fishing gears because they do not realize the impacts of using these gears and they do not have alternative livelihoods.
9. **Availability of market for different sizes of fish:** The fish market in Namsai is to date not sensitive to the gear used to catch fish and the size and quality of fish being marketed. The market accepts fish of different sizes and quality and has only differentiation by

riverine fish, fishery (cultured one) and imported (Chalani). Unfortunately, the market acceptance for riverine fishes of any size has grown so rapidly and is accepted by the local people even at high prices.

10. **Invasion of other fish species:** Invasive fish species compete with native species and resulting to food scarcity and mortality to native species. Fish like hybrid magur, rupchanda etc., are grown now a days by local people without any permission and information to Fishery dept. When their pond gets flooded these unwanted species get entry to the natural environment and their prolific growth and carnivorous feeding habit not only damage the feeding area but also to the juveniles of the native ones.
11. **Agricultural runoff:** Due to heavy rain in Namsai the run off residues majority from tea garden in form of pesticides, insecticides or fungicides ultimately comes to the river and it affects the planktonic diversity, force aquatic species to migrate, cause mortality to small animals, beneficial flora and fauna, infertility etc., which is serious issue for the ecosystem.
12. **Agricultural development**: Agricultural development in the flood plain restricts the breeding area of several native fish species like- *Channa* sp., pabda, magur, punti, murella, tangra, koi, singhi. Now a day due to the said reasons their availability is limited and rates are increasing day by day due to demand.
13. **Administrative control:** Some of the officers who represent the regulatory authority in some sites has also contributed to the continued use and increase of the destructive fishing gears especially in places like Namsai even in Arunachal Pradesh. It is especially more complicated when the officers who are posted by the regulatory authority are originally from these areas since it is difficult for an officer to stop his uncle or cousin from using a fishing gear that he has been used to. Easy market for juvenile fishes, brood fishes, selling of fish during monsoon season should to monitor on urgent basis both by local people and administration.

These destructive methods affect the ecosystem directly when in contact with for example indirectly by altering the relationship between those communities of plants, invertebrates and fishes that determine rates of bio-erosion. It is pointed out here for stopping the use of destructive fishing methods which will affect the livelihood of many fishermen since many fishermen rely on them for their livelihood, so some fisherman card and schedule of

fishing, mesh size regulation, species to be caught etc., norms can be implemented with proper planning and guidance. Present literature has revealed that the rivers are having rich potential of food fishes, ornamental fishes along with sport fishes. Some of these fish species are nearly threatened (*Tor tor*) and endangered (*Tor putitora*). Strategies are to be formulated by the administration and to implement them to eliminate these gears at source or if a ban could be imposed on stocking and sale of some of these gears at village level by the panchayat members or public representatives, then their use will be eradicated. It may be better to tackle them both from the supply side as well as the demand side for good results. In addition, low level of awareness on the impacts of destructive fishing practices and an I don‟t care attitude among across section of the fishers are important factors that contribute to the continued existence of destructive fishing practices. In terms of impacts, some fishing gears such as dynamites, electrical gears and small mesh size nets lead to excessive by-catch and juvenile wastage thus threatening sustainability. In addition, dynamite fishing causes serious damage to breeding ground, rearing places of juveniles, resulting in degradation that lasts for many years. It also causes injuries and death to humans when mishandled. It is important to have adequate surveillance capability to scare away those who may be tempted to use the destructive fishing techniques at village level by the local people and to boycott juvenile fishes, brooder fishes sold in local market caught by destructive fishing techniques and legal action to be taken care.

Conservation and Management:

1. Pradhan Mantri Matsya Sampada Yojana (PMMSY) – A scheme to bring about ecologically healthy and economically viable and socially inclusive development of the fisheries sector of India.

Healthy riverine fisheries are essential for maintaining overall ecosystem health and biodiversity conservation. Some major Management steps are also to be taken up by the district administration and Fisheries department:

- **Closed seasons** during breeding months (e.g., June–August for Indian major carps)
- **Minimum mesh size** for nets to avoid catching juveniles
- **Ban on destructive fishing methods**
- **Licensing & catch quotas** for fishers
- **Strict enforcement of laws**
- **Community participation**

- Co-management committees with fishers, government, and NGOs
- Fisher cooperatives for self-regulation
- Training fishers in sustainable practices

Some legal frame work to be implemented:

- **Inland Fisheries Acts** (State-level in India)
- **Wildlife Protection Act** for endangered aquatic species
- **Environment Protection Act** for water quality standards
- **National Fisheries Policy** promoting sustainable inland fisheries

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ROLE OF GREEN MANURES IN ORGANIC CROP PRODUCTION

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Introduction

In the face of increasing environmental challenges and the growing demand for sustainable farming practices, organic and natural crop production systems have gained significant attention. Organic and natural farming are production systems, which avoid or largely exclude the use of synthetically compounded fertilizers, growth regulators and livestock feed additives. It rely on crop rotations, green manures, legumes, crop residues, animal manures, off farm organic wastes and aspects of biological pest control to maintain soil productivity and tilth to supply plant nutrients and to control insect, pests, disease and weeds. These systems prioritize the use of natural inputs and aim to minimize the environmental impact of agricultural practices. Applying compost and crop residues together with green manures and liquid manures etc., in a more coordinated manner can release nutrients according to crop needs, maintaining increased productivity and promoting sustainability. (Kanwar *et al.*, 2006). Among all these green manuring is one of the important components, which play crucial roles in maintaining soil health, enhancing crop productivity,

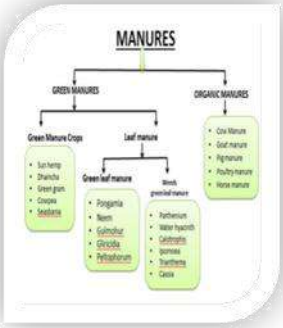
Green manuring involves the practice of growing certain crops specifically to improve soil fertility by fixing nitrogen, adding organic matter and enhancing soil structure. This practice is fundamental in organic farming, helping to reduce dependence on chemical inputs, enhance soil biodiversity and foster a more sustainable agricultural ecosystem. By promoting the efficient cycling of nutrients and improving soil structure, green manuring contribute to higher crop yields, better-quality produce, and long-term agricultural sustainability and environmental health.

Green manure

One component of organic farming is green manure. Green manure is a technique for enriching soil that involves adding green manure plants to the soil while they are still green or soon after they start to blossom. The presence of organic matter in the soil is the cause of green manures. One of the most crucial components of soil is organic matter, which is recognized for its true fertility. The availability of nutrients in the soil is impacted by the breakdown of this organic waste. Crops grown for green manure are categorized as green manure crops. Green manuring has been practiced by our farmers for decades. Green manure that is 40–50 days old is thought to be able to supply up to 80–100 kg N/ha. The crop can cover 50–60 kg of green manure, however only half of this N can be utilized. Sunnhemp, dhanicha, cowpea, mung, bean, guar, berseem, and so forth are examples of probable green manures (Sharma et al., 2013). During the *kharif* season, dhanicha, sunhemp, mung beans, and guar were grown; 8–21 tons of green manure and 42–95 kg of green manure crops were documented. N/ha. N/ha. Likewise, 12-29 tons of green and 67-68 kg N/ha of cowsari, cowpeas, and berseems can be produced throughout the rabi season (Vijaykumar *et al*., 2021).

Green manuring

Green manuring is defined as a practice of ploughing or turning the undecomposed green plant tissues into the soil for the purpose of improving the physical structure as well as the fertility of the soil by enrich the soil with organic matter and nutrients.



Types of Green Manuring

1. **Green manuring *in situ***

Green manure crops are grown and buried in the same field which is to be manured either as pure crop or as an intercrop.

Ex: Sunnhemp: *Crotalaria juncea*

Dhiancha: *Sesbania aculeta*

Phillipesara: *Phaselous tribolus*

Cluster bean: *Cyamopsis tetragonoloba*

Greengram, cowpea and other fodder legumes are cultivated by farmers as green manuring crops.

2. **Green leaf manuring (*Ex situ* green manuring)**

It refers to turning of green leaves and tender green twigs collected from shrubs and trees grown on bunds, waste lands and nearby forest areas into the soil.

Ex. Glyricidia : *Glyricidia maculata*

Sesbania *: Sesbania speciosa*

Karanj *: Pongamia pinnata*

- It is an practice of adding organic matter to the soil to improve soil fertility.
- Legumes are grown for atmospheric nitrogen fixation through Rhizobium symbiosis.
- The plants after 8 weeks of growth are incorporated into the soil to improve its fertility for raising another crop.
- A good crop of sunnhemp or Dhaincha with 8-12 t of green material adds about nearly 40-60 kg of nitrogen to the soil.
- Green manuring improves the N_2 status of soil and also biological activities of miroorganisms in the soil.

Desirable Characteristics of green manuring crops

1. Green manure crops should be of short duration, fast growing, high nutrient accumulation and biomass producing ability.
2. They should have multipurpose use.
3. They should have wide ecological adaptability
4. They must be tolerant to shade, floods, drought and adverse temperature
5. They must have high water use efficiency
6. They must possess the biological nitrogen fixing ability
7. They must have higher dry matter accumulation rate
8. They should release nutrient timely
9. They should be photo-insensitive
10. They must have higher seed viability
11. They should possess capacity for higher seed production
12. They should be amenable for easy incorporation
13. They must possess an ability to cross inoculation or responsive to incorporation.

Beneficial effects/ Significance of green manure crops

1) Green manure crops supply organic matter to the soil.
2) Conservation of plant food. Ex. Nitrate nitrogen
3) Leguminous crops used as green manure crops add considerable amount of nitrogen to the soil through atmospheric nitrogen fixation (Rhizobium symbiosis).

   Transfer of plant food from subsoil to surface

   (Nutrients (NPK) removal from **sub soil** by GMC ⟶

   Incorporation ⟶ Decomposition ⟶
4) Nutrients release to the **upper layers.**
5) Increase of availability of plant nutrients

   (Unavailable plant food ⟶ Readily available

   a. (Through action of plant roots)
6) Effect on bacterial life in the soil
   a. The various types of bacteria which convert organic nitrogen into ammonical and nitrate nitrogen are found flourish in the presence of organic matter furnished by the green manure crops.
7) When used as cover crops, green manure crops serve to protect the surface of the soil.
8) Green manure crops help to ameliorate the problematic soils.
   a. GMC grown for 4 to 5 years improve the permeability and helps to leach out the harmful sodic salts.
9) Pest control
   a. Some of the green manure crops like pongamia and neem leaves are reported to have pest control effect.
10) Green manure crops increase the yield of the crops to an extent of 15-20 % as compared to non-green manuring crops.

Role in Organic and Natural Crop Production:

- **Soil Health and Sustainability:** The green manuring focus on improving soil health, which is the foundation of organic farming. Healthy soils support better crop growth, enhance biodiversity, and reduce the reliance on synthetic inputs.

- **Reduced Chemical Dependency:** This method contribute to the primary goal of organic farming — reducing or eliminating the use of synthetic chemicals (fertilizers, pesticides, *etc*.) that can harm the environment and human health.
- **Nutrient Management:** They are vital in organic systems for effective nutrient management, helping to replenish and balance soil nutrients, particularly nitrogen, phosphorus, and potassium.
- **Enhanced Crop Productivity:** By improving soil fertility and structure, green manuring lead to improved crop yields and better quality produce.

Conclusion

Green manuring is vital tools for promoting sustainable agricultural practices. They enrich the soil, boost plant health, and contribute to environmental sustainability by reducing dependency on synthetic fertilizers and pesticides. Through these practices, organic and natural crop production systems can maintain high levels of productivity while improving long-term soil health and ecosystem resilience.

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SELECTION OF NEMATODE-FREE GUAVA SEEDLINGS IN THE NURSERY

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Introduction

Root-knot nematodes (Meloidogyne spp.) are one of the most destructive guava pests in tropical and subtropical regions. They are microscopic pests that hide in soil and roots. These Nematodes contribute to major yield losses in guava. If even one infected seedling is planted, it can infect the entire orchard over time. So, before planting guava seedlings, farmers must inspect and select only healthy, nematode-free seedlings. The following details help farmers make the right decisions while purchasing guava seedlings from a nursery.

Nematode Infested Seedlings

Healthy Seedlings

1. Purchasing of seedlings from a certified nursery:

- Buy seedlings only from certified, registered, or government-approved nurseries
- Avoid roadside vendors or unknown sources, as their plants may be nematode-infested.

Importance:

- The certified nurseries follow the practice of using neem cake, bioinoculants, and other organic amendments
- They follow better hygiene, pest management, and plant health practices
- They use the sterilized soil for the rooting medium
- These nurseries follow the practice of removing weak or infested seedlings from the nursery

2. Check the Seedlings to see whether they are free from root galls or knots:

How to Check:

- Gently remove one or two seedlings from their polybags
- Inspect the roots:

Healthy roots: White, fibrous, clean, and without galls.

3. Inspect the seedlings to ensure they have healthy, green leaves and uniform growth before purchasing:

Choose plants with:

- Uniform height
- Green, fresh-looking leaves
- without yellow, drooping, or curled

4. Check the seedlings to see whether they are grafted on nematode-resistant rootstock:

- Nematode-resistant seedlings are grafted on resistant species like:
- Psidium cattleianum
- Psidium friedrichsthalianum

5. Check whether the seedlings have hardened and ready for transplanting:

Select plants that are:

- 4–6 months old.
- Hardened (exposed to shade conditions).
- Not too young or soft.

6. Check the seedlings to see whether they are grafted by Ground Layering or Air Layering:

- In Ground Layering, the stems are bent in the soil and thus causes nematode infestation.

- In Air Layering, the roots are grown in the air, which reduces the chance of nematode infestation.

Final Advice to Farmers

- **Inspect before buying** – don't just look at the top part, check the roots too!
- **Ask questions at the nursery** – a good nursery will give honest answers.
- **Avoid rushing** – take time to pick the best planting material.
- One bad seedling can damage the health of your entire orchard.

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SERICIN AND ITS APPLICATIONS

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Introduction

Sericin, an outer protein of silk fibre which is derived from silkworm cocoons. It is a promising biomaterial for pharmaceutical applications due to its biocompatibility, biodegradability, antioxidant, anticoagulant, anti-carcinogenic and healing properties. It is used in drug delivery systems, wound healing, tissue engineering and also in cosmetic field. Sericin can be formulated into nanoparticles, hydrogels, films and other forms for diverse biomedical and pharmaceutical uses. This paper highlights the applications of sericin and commercially available sericin based products.

Characteristics of Sericin

- **Biocompatibility:** Sericin is well-tolerated by the body, minimizing adverse reactions.
- **Biodegradability:** Sericin degrades naturally in the body, reducing long-term concerns.
- **Bioactivity:** Sericin possesses various bioactivities such as antioxidant, antimicrobial, and anti-inflammatory properties.
- **Versatility:** Sericin can be processed into various forms (nanoparticles, hydrogels, films, etc.) for diverse applications.

Different roles of Sericin

1.Role of sericin in drug delivery system

Drug delivery systems can improve the effectiveness of therapeutic medicines by efficiently targeting, modulating release, or stabilizing the molecular state of drugs. Sericin has the potential as a drug delivery carrier due to its biocompatibility, adjustable morphology, chemical activity, and pH. Wang et al. developed a covalently cross-linked 3D pure sericin hydrogel that is

injectable and has physical and chemical properties that promote sustained drug release. This hydrogel could potentially serve as an efficient drug delivery system. Nishida et al. evaluated the release and biodegradation of a charged protein, fluorescein isothiocyanate - albumin using sericin of different molecular sizes, concentrations, and forms. Higher concentrations of sericin resulted in a longer release of the charged protein. These studies suggest that sericin can be used as a biomaterial for drug delivery.

- **Nanoparticles:** Sericin can be used to create nanoparticles for encapsulating and delivering drugs potentially improving drug solubility, stability and targeted delivery.
- **Controlled Release:** Sericin-based materials can be designed for controlled and sustained release of drugs, potentially reducing the frequency of dosing.
- **Targeted Delivery:** Sericin can be modified to target specific tissues or cells, enhancing drug efficacy and minimizing side effects.
- **Examples:** Sericin nanoparticles have been used to deliver doxorubicin, curcumin, and other drugs.

2.Role of sericin in tissue engineering

Materials that can be used in drug delivery, grafts and immobilizing matrices such as matrices in 2D (films) and 3D (scaffold) have been successfully made using a mixture of gelatine and sericin extracted from the silkworm *Antheraea mylitta*. Sericin has also been utilized for regeneration of cartilage and nerves. The scaffold composed of collagen-sericin infused with hyaluronic acid and chondroitin sulphate may offer temporary physical support to human adipose-derived stem cells in cartilage tissue engineering. Hyaluronic acid and chondroitin sulfate are regarded as the most advantageous pro-chondrogenic factors in developing new biomaterials for cartilage tissue engineering and adipose-derived stem cells. Meanwhile, Xie et al. have discovered that a pure sericin may be utilized for peripheral nerve regeneration in a rat nerve injury model. This sericin/silicone nerve guidance can act as a viable alternative to autologous nerve grafts in repairing damaged peripheral nerves, as it resulted in functional recovery that is similar to an autologous nerve graft.

3.Sericin as a wound healing material

When sulphonated, both fibroin and sericin exhibit an antithrombotic effect. Sericin, in particular, is a novel wound coagulant material because of its flexible and biocompatible nature as well as its ability to resist infections and absorbs water. It promotes skin healing without

causing any peeling of the skin during the regeneration process. Sericin has been used in regenerative medicine for the proliferation of keratinocytes and fibroblasts during the wound-healing process. It can induce fibroblast proliferation and collagen synthesis without the activation of pro-inflammatory cytokines. Thus, sericin can be formulated and used as a wound dressing or cream to control and prevent wound infection and treat burns and reduce scarring.

- **Wound Dressings:** Sericin-based materials, like nanofibrous matrices and hydrogels, are being explored for wound dressings, particularly for diabetic foot ulcers.
- **Scaffolds:** Sericin can form scaffolds for tissue regeneration, with studies focusing on bone, skin, cartilage, and adipose tissue.
- **Biomimicry:** Sericin's natural affinity for keratin (a protein found in skin and hair) makes it suitable for skin and wound care.
- **Examples:** Sericin has been combined with hydroxyapatite for periodontal bone regeneration and used in cardiac tissue regeneration studies.

4.Sericin as a raw material for making contact lenses

Silk sericin has biological beneficial properties helpful in the development of contact lenses. The biocompatible graft polymers were prepared with methyl methacrylate or styrene along with sericin to develop a raw material for contact lenses. Oxygen-permeable membranes made of fibroin and sericin with 10-16 % water is used for contact lenses and as artificial skin.

5.Sericin as a medicine for improving digestion and curing digestive diseases

Food containing sericin has been found to alleviate constipation, inhibit the progression of bowel cancer and enhance the absorption of minerals. When consumed orally, sericin induces a dose-dependent reduction in the development of colonic aberrant crypt foci. It has also been shown to decrease the incidence and number of colon tumors due to its potent anti-cancer activity.

Application of Sericin in the dental field

Sericin as implant coated bio active material

Numerous techniques have been developed over the years to coat or chemically modify titanium implantable surfaces for dental applications in order to improve the implant response to oral micro-biota to reduce the risk of implant failure. A natural biomolecule that has been shown to possess the interesting biological characteristics is silk sericin. An in vitro study was done to evaluate the effectiveness of different experimental protocols to obtain a sericin-based coating on

medical grade Titanium able to reduce microbial adhesion and biofilm formation on the dental implant surface.

Commercially available oral gargle containing silk protein

Sericin based Commercial Products

SERIDERM

Accelerated Wound Healing

Seriderm is a non-adherent, absorbent wound dressing designed using silk proteins for accelerated wound healing. It promotes faster and efficient healing in complex wounds such as diabetic feet ulcers, bed sores and second degree burns. In lab and animal studies, Seriderm has outperformed leading global products in all wound healing parameters.

SERIOSS

Excellence in bone repair

Serioss is an osteo-conductive bone void filler powered by silk protein that can be used to fill cavities in bone caused by trauma, infection, cancer, etc. Serioss provides the appropriate environment for bone cells to thrive and function. In animal and lab studies, Serioss has outperformed leading global ceramic-based bone void fillers with 2X improvement in all bone repair parameters, thereby reducing post-surgical complications.

SERIMAT

Superior Soft Tissue Regeneration

Serimat is a protein based matrix engineered to promote soft tissue regeneration. Its unique design ensures appropriate surface texture, suitable pore size and porosity with excellent mechanical properties. Moreover, Serimat is suturable and comfortable, making it

an ideal soft tissue regeneration matrix in implant-based breast reconstruction surgery and other clinical applications. Serimat has proven biocompatibility and outperforms leading global products in soft tissue and blood vessel formation. In lab and large animal (pig model) studies, Serimat was well tolerated at implemented sites.

Traditional Silk Sutures

Due to its biocompatibility, biodegradability, antioxidant, anticoagulant and healing properties, traditional silk sutures are often made from silk fiber of *Bombyx mori* (domesticated silkworms). Sercin has a major role in tissue regeneration and to prevent inflamation on surgical sites. These sutures are typically braided and coated (e.g., with silicone or beeswax) to improve handling and tissue passage.

Hydrogels

These hydrogels are three-dimensional, water-based gels which contain sericin as a major component that can be used to encapsulate cells and biomaterials, providing a moist environment for healing.

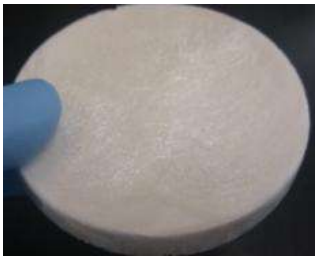
Nanofibers

These materials offer a large surface area for cell attachment and can be designed to release therapeutic agents gradually.

Films

Sericin films can be used as a protective barrier over the wound, helping to maintain moisture and promote healing.

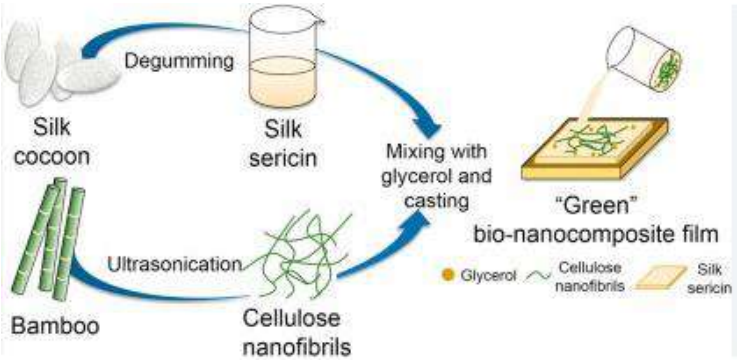
Sericin Film



Sericin Sponge

Composites

Sericin can be combined with other materials, such as nanoparticles, plant extracts, or antibiotics, to enhance its wound healing properties.



Natural Soap with Integral Sericin

A vegetable soap with 3% integral Sericin helps in deep cleaning without irritation and nourishing and hydrating the skin, that will recover its smoothness and silkiness. Its daily use can provide excellent results when treating eczema, psoriasis and dermatitis.

Face cream

Sericin is renowned for its ability to enhance skin elasticity, reduce the appearance of fine lines and provide a protective barrier. Its gentle, non-irritating nature makes it suitable for sensitive skin products such as moisturizing creams, night creams, face wash etc. contributing to a luxurious and nourishing experience in various cosmetic applications.

Conclusion

In summary, sericin is a promising biomaterial with diverse applications in cosmetics and pharmaceuticals, particularly in drug delivery, wound healing, and tissue engineering. Further research and development are needed to optimize sericin-based products and address existing challenges.

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TAMARIND BASED PRODUCTS

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Introduction

Tamarind has been described as one of the common and most important trees of India. India is the world's top producer, exporting several thousands of tonnes of seed, seed powder and fruit pulp each year. Tamarind trees are often grown in gardens and along roadsides and are cultivated commercially in plantations. India is the only producer of tamarind on a commercial scale. A large part of India's production of tamarind is exported to West Asia, Europe and America, where it is used for food specialties like Worcestershire sauce. This spice also comes in the forms of pulp and juice concentrates which mainly go into the preparation of cool drinks, sea foods and a range of sophisticated cuisine.

Tamarind

Tamarind is native to tropical America and this plant is widely used throughout Asia and it has acquired the common name Assam, meaning, simply, 'acid' as they are used as acid flavours in the food Industry. The many tamarind cultivars are divided into two basic categories: sweet and sour. India mainly grows sour cultivars in orchard-like plantations. Tamarind is widely used thorough the world. Tamarind pulp concentrate is widely used in Indian and Middle Eastern cooking.

Tamarind products

Tamarind can be found in various forms like concentrated pulp with seeds, a canned paste, whole dried pods, or powdered. It is available in Indian and some other Asian markets. There is a wide variety of tamarind products available in the market for consumption. They include tamarind paste, seedless dried tamarind, tamarind pods, tamarind concentrate, tamarind

syrup, tamarind drink concentrate, tamarind sauce, tamarind chutney, tamarind dipping sauce, tamarind gelatin, tamarind candy etc. Tamarind may also be used as a base for delicious raw or cooked chutneys, its fruity acidity combining well with sugar, chilli and other flavours. Moreover tamarind concentrates are extensively used as an ingredient and an effective substitute for vinegar, tomatoes and lemon juice.

Conclusion

Tamarind, an essential ingredient in the South Indian cuisine and a host of processed food items across the globe, can also offer livelihood security in rural and tribal areas, experts indicate. Its organized processing, supported by cold storage facilities, is found to be ideal for ensuring market price stability and rural employment. India is the largest producer and exporter of range of raw and processed spices. Processed spices demand is directly linked with its consumption in food processing industry and this is set to grow in India in coming period with growth of population and fast changing food habits as well as increase in spending power of the middle and upper class in India.

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THE HIDDEN WEALTH OF LICHENS: NATURE'S REMARKABLE MULTI-TASKERS

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Abstract

Lichens are unique organisms that consist of a fungal partner, known as the mycobiont, and an algal or cyanobacterial partner called the photobiont. They can adapt to various and harsh environments. Their ability to resist drought, changing temperatures, and pollution makes them important indicators of environmental health. Epiphytic lichens, in particular, gather airborne pollutants and heavy metals, offering a glimpse into air quality issues. In addition to their ecological importance, lichens contain bioactive compounds that have antimicrobial, antioxidant, and anti-inflammatory effects. This makes them useful in traditional medicine and modern healthcare. They provide sustainable options in agriculture by effectively managing plant diseases with natural antifungal and antibacterial substances. Moreover, lichens serve as an eco-friendly source of natural dyes and have a significant role in nanotechnology by helping to create nanoparticles with antimicrobial properties. Because of their many useful qualities and wide-ranging applications, lichens are an important natural resource with great potential for future research and industrial use.

Keywords: Lichens, Remarkable organisms, Hidden wealth, Multi-Taskers

Introduction

Lichens are a unique biological partnership between a fungal component, called the mycobiont, and either an algal or cyanobacterial component, known as the photobiont. This

symbiotic relationship is key to their classification as separate organisms. Most lichens grow on land, but some can survive in the ocean and adapt to living in both water and salty conditions. Others can deal with various challenges, such as extreme temperatures and air pollution. Lichens serve as a great example of a symbiotic relationship between two different biological kingdoms, fungi and algae. In 1868, Swiss botanist Simon Schwendener made an important discovery about the dual nature of lichens. The lichen symbiosis involves a mutualistic relationship, where the fungal component gets carbohydrates from the photobiont. In exchange, the photobiont receives water, essential minerals, and protection from drying out and harmful light, all provided by the fungal partner. Lichens are among the slowest-growing plants. A growth rate of 1 cm per year is considered high for them. They have the impressive ability to tolerate harsh atmospheric conditions.

Another interesting aspect of lichens is their secondary metabolites. Lichens have a unique metabolism that allows them to cope with the negative effects of their environment, helping them develop a special survival strategy. The secret to their survival is their ability to withstand long periods of drought. Lichens thrive in mountainous areas at altitudes up to 2400 meters above sea level, and they can even be found in Antarctica, where temperatures can drop to −60˚C. They inhabit a wide range of settings, including soil, tree bark, roots, and decaying stumps. Often, they colonize surfaces enriched with moisture due to human activities and develop specialized associations. Moreover, lichens can thrive despite changes in temperature and humidity in nutrient-poor soils and even on rocky surfaces. They are sensitive to environmental disturbances, making them useful indicators of forest ecosystem health and global change.

Biomonitors of Environmental Contamination

Air pollution is widely seen as one of the biggest environmental problems we face today. The decline in air quality caused by increasing pollutants in the atmosphere negatively impacts living organisms and is a serious global issue. Epiphytic lichens make great bioindicators because they can accumulate contaminants over long periods beyond their own needs. As a result, these organisms are a valuable method for measuring the presence and availability of specific pollutants in the environment. The lichen species *Canoparmelia caroliniana* can be used as a strong bioindicator for the accumulation of metals and agrochemicals. Lichens lack epidermis, stomata, and cuticle, which means they cannot exchange gases. This feature allows

them to absorb nutrients and minerals directly from the atmosphere through their entire surface. Lichens produce a wide range of secondary metabolites that play important roles in ecological interactions and help them adapt to environmental changes. They obtain nutrients and heavy metals through different processes, including rainfall, dust deposition, and the underlying substrate from both natural and man-made sources. Natural sources include volatile metals, marine aerosols, volcanic activity, leachates from leaves and bark, and suspended particles from soil and rocks. Lichens are known for being efficient accumulators and show different sensitivities to metals. To take in nutrients from their environment, lichens use several methods such as trapping particles, sorbing electrolytes, exchanging ions, uptaking intracellularly, and hydrolysis. Among the different types of lichens, epiphytic lichens are known to be the most sensitive.

Health Promoters

Lichen is a nutrient-rich and adaptable food source that has been regularly consumed throughout history. These valuable organisms are now being studied for various uses beyond just food. Lichens contain many beneficial elements that are crucial for life and normal body functions. The presence of ash in lichens shows that they are high in several minerals such as calcium, sodium, potassium, zinc, and copper. These minerals support many bodily processes. They are important for enzyme activity, muscle function, maintaining acid-base balance, and regulating osmotic pressure. *Usnea florida* serves as a promising antimicrobial in the food industry and can help treat various illnesses, including the common cold, influenza, respiratory issues, sore throats, and digestive problems. Lichen extracts have high levels of total polyphenolic compounds, including depsides, depsidones, dibenzofurans, and other phenolic derivatives, which give them strong antioxidant properties. In traditional Argentinian medicine, teas made from *Usnea densirostra* and *Usnea durietzii* were used on the skin. These teas acted as astringents, antiseptics, and anti-inflammatory agents.

Plant Disease Management

Microbial pathogens cause major problems in agriculture worldwide. They lead to an estimated annual loss of 10-15% of the world's primary crops. The widespread use of synthetic chemicals creates serious environmental issues. These issues include the rise of fungicide-resistant pathogen populations, soil compaction, and various types of pollution.

Lichens contain specific antimicrobial compounds that can fight against plant pathogens such as fungi and bacteria. Compounds derived from lichens like lecanoric acid, lobaric acid, usnic acid, and vulpinic acid have shown antibacterial effects against the Gram-positive bacterium *Clavibacter michiganensis* subsp. *michiganensis*. Notably, usnic acid and vulpinic acid were particularly effective against this pathogen. Usnic acid acts as a selective antifungal agent that targets fruit rot pathogens. Vulpinic acid has a broad range of antifungal properties against various plant-fighting fungi. It is a powerful compound that can be used to manage Sclerotinia rot diseases in different vegetables and fruits. Lecanoric acid specifically inhibits the growth of *Rhizoctonia solani*. Using this lichen compound in golf course management offers an environmentally friendly way to tackle brown patch disease, which *R. solani* causes in creeping bentgrass (*Agrostis palustris* Huds.) and perennial ryegrasses grown on fairways.

Preparation of Dyes

Lichens are a promising source of natural dyes. *Everniastrum cirrhatum* contains secondary metabolites like salazinic acid, atranorin, and protolichesteric acid. Salazinic acid is especially important for creating orange and brown dyes from lichens. Metabolites such as fumarprotocetraric acid, protocetraric acid, usnic acid, and atranorin mainly produce various shades of pink and are found in the genus *Cladonia*. The genus *Heterodermia* contains secondary metabolites like zeorin and atranorin, which may help explain the diverse colors in this group. Most synthetic dyes use mordants that contain heavy metals, making them harmful to the environment. Lichen dyes do not require mordants, making them completely natural and environmentally friendly. The unique musky smell of lichen-dyed fibers protects them from insect damage, improving their shelf life and overall durability.

Biogenesis of Nanoparticles

Lichens are known for having a high concentration of phenolic compounds and polysaccharides, including lichenan and isolichenan. They also contain various secondary metabolites, notably protolichesterinic acid and fumarprotocetraric acid. Lichen extract is recognized as an effective reducing and capping agent for nanoparticles (NPs) because these organisms are abundant, grow quickly, and are environmentally sustainable. The functional groups in the secondary metabolites from lichen extracts are crucial for preventing the aggregation of nanoparticles (NPs). This quality significantly improves the fabrication and stabilization processes of NPs.

The aqueous-ethanolic extract of *Usnea longissima* can facilitate the extracellular synthesis of silver nanoparticles (Ag-NPs) from silver nitrate under controlled lab conditions. *Parmotrema tinctorum* can also synthesize silver nanoparticles (Ag-NPs) from silver nitrate using an environmentally friendly method. Aqueous extracts of *Parmotrema praesorediosum* and *Ramalina dumeticola* were used for the extracellular synthesis of Ag-NPs over 72 hours at room temperature. Both lichen species successfully produced Ag-NPs; however, *R. dumeticola* showed superior bioreduction activity. The Ag-NPs from *R. dumeticola* were spherical with an average diameter of 20 nm, while those from *P. praesorediosum* were also spherical but had a larger average size of 42 nm.

Cetraria islandica was an efficient biological source for synthesizing both silver nanoparticles (Ag-NPs) and gold nanoparticles (Au-NPs). The ethanolic extract of the lichen *Parmotrema clavuliferum* was used for the green synthesis of silver nanoparticles (Ag-NPs), using silver nitrate as the precursor. The green synthesis of titanium dioxide (TiO_2) nanoparticles was achieved with an ultra-sonicated aqueous extract of *Parmotrema austrosinense* offering an efficient, eco-friendly, and cost-effective method. The resulting TiO_2-NPs showed antimicrobial properties effectively combating fungal phytopathogens such as *Xanthomonas phaseoli* and *Fusarium oxysporum* which are known to cause major crop yield losses.

Conclusion

Lichens are intriguing natural organisms with many unique traits. They have a variety of uses in different fields. Lichens can serve as food, spices, medicines, and in several industrial processes, including tanning, brewing, distillation, dye production, and cosmetics manufacturing. They also have antimicrobial properties that can help manage diseases in plants and humans. Furthermore, lichens are important in the biosynthesis of nanoparticles, providing a green and eco-friendly way to produce them. Despite a lot of research, lichens still have many hidden features and untapped potential that need more investigation. Overall, lichens are remarkable organisms with versatile capabilities and a wide range of applications in many areas.

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SHREE ANNA (MILLET) PRODUCTION AND PROMOTION IN INDIAN AGRICULTURAL SYSTEMS

Article ID: AG-V05-I08-115

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Abstract

The surging demand for millets is significantly boosting farmers' incomes and elevating their social standing, creating vibrant and resilient farming communities. In India, a variety of innovative initiatives are championing millet cultivation, celebrated for its rich nutritional profile and remarkable adaptability to drought-prone landscapes. Among the prominent programs is the National Food Security Mission for Nutri-Cereals, which aims to secure a nourishing future, and the Production Linked Incentive Scheme for Millet-Based Products, designed to stimulate production and innovation. Regional endeavours, such as the Odisha and Chhattisgarh Millet Missions, are also making waves, focusing on revitalizing these ancient grains. These initiatives not only aim to enhance agricultural practices and diversify crop options but also seek to reignite a passion for millet consumption among communities. Together, they forge a path toward robust food security and sustainable agricultural practices, all while confronting the pressing challenges of climate change. Through these efforts, millets are not just a crop; they are a beacon of hope for a healthier, more sustainable future.

1. Introduction

Millets, known as Shree Anna, are extraordinary crops that are often overlooked but are brimming with nutrients and possess incredible resilience against climate challenges. These ancient grains hold vast potential to tackle some of the most pressing global issues we face today, such as food security, malnutrition, and climate change. By unlocking the rich genetic

diversity of major and minor millets, researchers can create innovative varieties that flourish even in the harshest environments and are packed with essential micronutrients. This transformative approach not only has the power to uplift smallholder farmers, particularly women, but also equips them to cultivate sustainable and highly nutritious crops. Imagine a world where food security is not just a possibility but a reality for all. By investing in millets, we can pave the way for equitable access to nourishment and create a healthier, more resilient future. Let us embrace these hidden gems and harness their potential to change lives and landscapes for the better.

2. Significance of growing minor millets in India

India, a vast and diverse nation, faces important challenges in achieving food and nutritional security for its large population. However, the cultivation of minor millets presents a constructive opportunity to address these issues. With their high nutritional value, drought tolerance, and ability to thrive in poor soil conditions, minor millets can significantly enhance food security, particularly in rural and tribal areas where these crops have traditionally been grown. Moreover, minor millets are essential for fostering ecological balance and promoting sustainable agriculture in India. These crops require minimal inputs, are less water-intensive, and contribute to soil fertility, making them particularly suitable for India's rain-fed farming systems. By prioritizing the cultivation of minor millets, we can create new income opportunities for small and marginal farmers, who represent a large segment of India's agricultural workforce. This can lead to rural development, poverty reduction, and improved livelihoods for many communities. Additionally, the role of minor millets in tackling the issue of malnutrition in India cannot be overstated. These crops are rich in vital micronutrients such as iron, zinc, and calcium, which are essential for maintaining good health. By integrating minor millets into everyday diets, we not only reduce our dependence on imported grains but also enhance nutritional security and contribute to a healthier, more sustainable food system for all. Embracing the cultivation and consumption of minor millets can be a valuable step towards a more resilient and prosperous India.

3. Cultivation of minor millets may bring resilience to farmers and farming community

Cultivating minor millets offers a transformative opportunity for farmers and farming communities, fostering resilience and growth in several key areas.

3.1 Climate Resilience: Minor millets are exceptionally adaptable to challenging weather conditions and require minimal water and resources to thrive. This resilience makes them a valuable crop for regions that experience drought or extreme temperatures, ensuring farmers have a stable source of income.

3.2 Soil Health and Biodiversity: The cultivation of minor millets plays a vital role in promoting soil health. These crops help prevent erosion, enhance soil structure, and support biodiversity. By integrating minor millets into their farming practices, farmers can adopt more sustainable methods that reduce reliance on chemical fertilizers and pesticides.

3.3 Economic Empowerment: Growing minor millets presents a significant opportunity for farmers to bolster their livelihoods. With the ability to grow these crops on marginal lands, smallholder farmers can increase their income and financial stability while lowering operational costs.

3.4 Food Security and Nutrition: Minor millets are nutrient-dense, providing a wealth of essential vitamins, minerals, and proteins. By prioritizing the cultivation of these crops, farmers can contribute to improved food security and nutrition within their communities.

3.5 Market Opportunities: As the popularity of minor millets rises, farmers have the chance to tap into new market opportunities. This growing demand can enhance their income and elevate their social status, cultivating a vibrant and resilient farming community. In conclusion, the cultivation of minor millets represents a constructive pathway toward strengthening the resilience of farmers and their communities. It equips them to effectively address challenges related to climate change, economic shifts, and social dynamics, fostering a more sustainable agricultural future.

4. Schemes and policies to promote millet cultivation in India

Several schemes and policies have been initiated in India to promote millet cultivation, recognizing their nutritional value and potential for drought-prone areas. These include the National Food Security Mission (NFSM)-Nutri-Cereals, Production Linked Incentive Scheme for Millet-Based Products (PLISMBP), and state-level initiatives like the Odisha Millet Mission and the Chhattisgarh Millet Mission etc.

4.1 National Food Security Mission (NFSM)-Nutri-Cereals: This mission focuses on increasing the production and productivity of millets, particularly in rain-fed areas. It provides incentives to farmers for crop production and protection technologies, seed production, and

capacity building. The National Food Security Mission (NFSM) for Nutri Cereals is making significant strides in enhancing agricultural practices for farmers by providing essential incentives through state and union territory governments. This initiative is thoughtfully designed to support a diverse range of enhancements, including advanced crop production and protection technologies, practical crop system demonstrations, and the production and distribution of certified seeds from newly developed varieties and hybrids. This mission actively promotes sustainable farming practices by introducing integrated nutrient and pest management techniques, innovative farming tools, resource conservation machinery, and effective water-saving devices. Additionally, this mission is committed to empowering farmers through comprehensive training programs during the cropping season, as well as hosting organized events and workshops that foster community engagement and education. Furthermore, seed minikits are distributed, and information is shared effectively through print and electronic media to reach a wider audience.

The NFSM also encourages the formation of Farmer Producer Organizations (FPOs) dedicated to Shree Anna and supports the establishment of Centers of Excellence (CoE) and seed hubs, ensuring that farmers have access to the best resources and knowledge. Various states, including Assam, Bihar, Chhattisgarh, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Rajasthan, Tamil Nadu, Uttarakhand, and Uttar Pradesh, are actively participating in Millet Missions to promote Shree Anna. With the goal of establishing India as a global center for Shree Anna production, the Indian Institute of Millets Research (IIMR) in Hyderabad has been designated as a Centre of Excellence. This initiative will help facilitate the exchange of best practices and drive research and technological advancements at both national and international levels.

4.2 Production Linked Incentive Scheme for Millet-Based Products (PLISMBP):

Launched by the Ministry of Food Processing Industries (MoFPI), this scheme aims to promote value addition to millets by incentivizing the manufacturing and sale of millet-based products. he Government is also popularizing Agri-Infrastructure Fund Scheme to invite farmers/FPOs/Entrepreneurs to avail the benefit for setting up primary processing units in Shree Anna. Government is also promoting Shree Anna based startups to increase the demand of Shree Anna. This scheme focuses on promoting the use of millets in food products and increasing value addition in India. It incentivizes the manufacturing and sale of selected millet-based products,

both for domestic and export markets. The scheme, which runs from 2022 to 2027, has an outlay of ₹800 crore and is implemented by the Ministry of Food Processing Industries (MoFPI). The primary objective of the PLISMBP is to encourage the use of millets in Ready-to-Eat (RTE) and Ready-to-Cook (RTC) products, and to incentivize their production and sale in domestic and export markets. The scheme covers a range of millet-based products, including-Breakfast Cereals and Bars: Muesli, breakfast cereal, puff, flakes, granola, and breakfast protein bars; Bakery Products: Millet cookies, cakes, and rusks; Snacks and RTC/RTE Products: Noodles, pasta, chips, crisps, bread, papad, khakhra, ice creams, and extruded snacks. To be eligible for the scheme, applicants must meet certain criteria, including: minimum sales requirement, udyam registration certificate and manufacturing requirement for engagement in manufacturing or intending to manufacture eligible products in India. The scheme offers incentives to selected applicants based on their incremental sales of eligible products. The incentive rate varies from 10% to 8% over the five-year period.

4.3 Poshan Abhiyan of the Ministry of Women and Child Development:

Shree Anna holds a special place in the Poshan Abhiyan initiative by the Ministry of Women and Child Development, reflecting our collective commitment to nutrition and well-being. The Ministry of Food and Public Distribution is also taking important steps by updating its guidelines to boost the procurement of Shree Anna through the Targeted Public Distribution System (TPDS), Integrated Child Development Services (ICDS), and Mid-Day Meals. This effort underscores the importance of nourishing our communities. State Governments and Union Territories are being encouraged to enhance their procurement of Shree Anna, recognizing its potential to contribute to better health for all. To further support this grain's journey, an Export Promotion Forum has been established, dedicated to promoting Shree Anna in the international market and facilitating its marketing and development. Additionally, the Food Safety and Standards Authority of India (FSSAI) is leading the charge under the Eat Right campaign to foster awareness about the benefits of including Shree Anna in our diets. This initiative aims to inspire everyone to embrace a healthy and diverse diet, ultimately nurturing our bodies and strengthening our communities.

4.4 Inclusion in Public Distribution System (PDS): Millets are increasingly being included in India's Public Distribution System (PDS) to enhance food security and promote nutritional diversity. This inclusion is part of a broader strategy to encourage the cultivation and

consumption of millets, which are considered highly nutritious and climate-resilient crops. Reasons for inclusion are potential to provide nutritional security offering a more balanced diet compared to relying solely on rice and wheat, their capacity to tolerate drought and thrive in marginal lands, making them a sustainable option for food production in changing climatic conditions, diversify the food basket, reducing dependence on major grains and provide support to the farmers for procurement of millets through PDS with a guaranteed market and income, incentivizing them to cultivate these crops.

4.5 National Initiative on Millets: The "National Initiative on Millets" represents a vital step forward for India in promoting the production and consumption of millets, which are not only highly nutritious but also crucial for ensuring food security. This initiative is designed to elevate awareness around the myriad benefits of millets, bolster their cultivation, and position India as a leading global hub for millet production. By declaring 2023 the International Year of Millets, we are sending a strong message about the importance of these grains. It also involves implementing policies like the Odisha Millet Mission, now known as Shree Anna Abhiyan.

4.6 Pradhan Mantri Rashtriya Krishi Vikas Yojana (PM RKVY): This scheme encourages farmers to diversify their crops, which can include millets, by providing financial assistance. It is a significant part of the larger “Krishionnati Yojana”, which has a substantial budget for 2025-26.

4.7 Other State Government Initiatives:

4.7.1 Odisha Millet Mission: Odisha Millet Mission is a flagship program initiated by the Department of Agriculture and Farmers' Empowerment, Government of Odisha. The mission aims to revive millets in farms and on plates, promoting nutritional security and sustainable agricultural practices. Its major objectives are to encourage farmers to grow millets, which are resilient to climate change and require less water, promote consumption of millets, rich in nutrients, to address malnutrition and related health issues, foster eco-friendly farming practices, reducing reliance on chemical fertilizers and pesticides.

4.7.2 Chhattisgarh Millet Mission: The Chhattisgarh Millet Mission, launched in September 2021, aims to establish Chhattisgarh as a leading state in millet production in India. The initiative focuses on promoting the cultivation of Kodo millet, little millets, and Finger millet, with a special emphasis on tribal areas. It also aims to revive millet cultivation and consumption, encompassing the entire value chain from production to linking with government schemes.

The program is implemented across 85 blocks in 20 districts, with a dedicated budgetary allocation.

4.7.3 Uttar Pradesh Millets Revival Programme:

The Uttar Pradesh Millets Revival Programme (UPMRP), approved by the State Cabinet in 2023, represents a significant initiative to enhance the production, processing, and consumption of millets. This program is designed not only to strengthen the millet value chain but also to elevate farmers' incomes and ensure nutritional security for the population. Here are the constructive features of the scheme:

1. Empowering farmers through seed distribution: To encourage millet farming, the government will distribute complimentary mini-kits of millet seeds. This initiative particularly aims to support registered farmers and recipients of the Kisan Samman Nidhi, with special emphasis on empowering women and SC/ST farmers for more inclusive agricultural practices.

2. Reviving Traditional Farming Practices: The Millet Revival Program strives to restore traditional millet cultivation, known as Shree Anna, and enhance rural livelihoods. By collaborating with agricultural universities and research institutions, the program will promote the development of high-yield millet varieties and improved farming techniques.

3. Strengthening connections with industries: The initiative seeks to forge connections between millet farmers and food processing industries as well as retail chains, ensuring that farmers receive fair prices for their products.

4. Encouraging innovation through startup support: The program will provide financial and technical support to startups and small businesses focused on millet-based products, fostering innovation and creating valuable employment opportunities within the sector.

5. Enhancing export potential: Efforts will be made to position Uttar Pradesh as a leading player in millet exports. By improving quality standards, enhancing branding, and establishing connections with international markets, the state aims to expand its reach and impact.

6. Promoting health awareness: The government aims also undertake awareness campaigns to inform the public about the numerous health benefits of millets, encouraging their incorporation into everyday diets. Through the Millet Revival Program, Uttar Pradesh is poised to not only promote sustainable agricultural practices but also drive nutritional diversity, improve health indicators, and build a robust human capital for future generations.

4.7.4 Other state-level initiatives: Several other states, including Assam, Bihar, Karnataka, and Tamil Nadu, have also launched their own millet missions

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IDENTIFICATION OF DIFFERENT PESTS OF SOYBEAN AND MANAGEMENT BY USING INTEGRATED PEST MANAGEMENT PRACTICES

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Introduction

Soybean (Glycine max L. Merr.) is one of the most important Kharif oilseed crops in Maharashtra, cultivated primarily for its high-protein meal and edible oil. The crop was introduced in the state during the 1970s and has since become a major component of the oilseed economy. Maharashtra's agro-climatic conditions—particularly in Vidarbha, Marathwada, and parts of Western Maharashtra—are well-suited for soybean cultivation, with sowing generally carried out during mid-June to early July under monsoon rains. Nitrogen fixation improves soil fertility for subsequent crops like wheat, chickpea, or sorghum. Reduces dependency on synthetic nitrogen fertilizers. In India, soybean is mainly grown in the states of Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, Andhra Pradesh, Chattisgarh, Nagaland and Gujarat as a rainfed crop during the rainy (Kharif) season.

In 2024 area under soybean was 45.005 lakh ha in Maharashtra. Maharashtra is India's second-largest soybean producer after Madhya Pradesh, accounting for around 30–35% of national production. Major producing districts Latur, Amravati, Akola, Yavatmal, Parbhani, and Washim. Initially, the soybean was free of diseases and insects in India. However, its continuous cultivation with simultaneous increase in area has led to increase in disease and insect incidence. Currently, soybean is severely attacked about half a dozen major of insect pest and several major weeds. Yield losses due to individual disease/insect species ranges from 20 to 100 per cent.

Hence there is need to educate the farmers about identification of pests and their management practices.

Major Insects of Soybean:

1. Stem fly (*Melanagromyza sojae* Zehntner)
2. Tobacco caterpillar (*Spodoptera litura* Fabricius)
3. Green semiloopers (*Chrysodeixis acuta* Walker, Gesonia gemma and Diachrysia orichalcea Fabriciussensu Hübner)
4. Girdle beetle (*Obereopsis brevis* Gahan)
5. Pod borer (*Helicoverpa armigera* Hubner)
6. White fly (*Bemisia tabaci* Gennadius)

1. Stem fly (*Melanagromyza sojae* Zehntner) Agromyzidae : Diptera

Marks of Identification:

- Adult fly is small, black in colour 2 mm length.
- Female fly is larger than male.
- Maggot is apodous, light yellow in colour and 3-4 mm in length.

Nature Damage:

- After hatching maggot bore the leaf vein.
- Through petiole get entry into the stem and feed inside the stem tissue.
- Due to the feeding galleries are formed, branches dried and plant killed.

Life Cycle:

- Stem fly lay eggs in leaf tissue or on leaves.
- Incubation period is 2-7 days.
- Maggot period is 10-15 days.
- Pupation take place in stem / soil and pupal period lasts for 7-10 days.
- Adult period is 5 days and total life cycle is completed within 25-30 days.

2. Tobacco Leaf eating caterpillar: *Spodoptera litura Noctuidae*: Lepidoptera

Mark of Identification:

- Adult moth is stout with wavy white markings on the brown

forewings and white hind wings with a brown patch along its margin.

- Larva is stout, cylindrical, pale brownish with dark markings.
- The body may have row of dark spots or transverse and longitudinal grey and yellow bands.

Nature of Damage:

- Neonate, green caterpillars feed on the leaves voraciously and present an appearance to the field as if grazed by cattle.
- Since this pest is nocturnal in habit larvae hide under the plants, cracks and crevices of soil and debris during the daytime.
- Faecal pellets are seen on the leaves and on the ground which is the indicator of the pest incidence.

Life Cycle:

- Eggs are laid in groups and covered with hairs on the leaves.
- The egg period is 4-5 days. The larval period is 14-21 days.
- It pupates in earthen cells in soil for 15 days. Life cycle is completed 30-40 days.

3. Green semiloopers (*Chrysodeixis acuta* Walker Noctuidae: Lepidoptera

Marks of Identification:

- The caterpillar is a glassy green in color with 3 pairs of abdominal legs (prolegs) that typically bend their body in a semi-loop while walking.
- Adult moths are brown, the forewing bears a dark brown pattern with 2 characteristic silver spots
- Black scales are on the median region with tiny silver spots on the median line of the forewing.

Nature of Damage:

- The full-grown larva feeds on foliage, flowers and pods. In severe infestation, it defoliates the plant leaving behind only midribs.
- The newly emerged caterpillars feed on the lower surface of the upper canopy of soybean leaves in a characteristic manner, leaving the top epidermis intact.

Life Cycle:

- The female moth lays tiny white creamy eggs on the underside of the leaves or young stems.

- It pupates on leaves undersides in a silken cocoon from egg to adult, it will take anywhere from 25 to 30 days.

4. Girdle beetle (*Obereopsis brevis* Gahan)

Marks of Identification:

- Adult beetle light brown, antennae as long as body length.
- Grub is apodus, whitish yellow in colour.

Nature Damage:

- Grub bore the stem up to root and feed inside the stem tissue due to feeding plant dried and reduction in yield up to 85%.
- Girdling of stems and petioles.

Life Cycle:

- Female make girdle on petiole, stem, branches and lay eggs inside the girdle.
- Egg period 4-8 days, grub period 32-62 days.
- Grub enters in diapauses stage and pupated inside stem pupal period 8-11 days and after monsoon showers adult emerges.

5. Gram Pod borer: *Helicoverpa armigera* Noctuidae: Lepidoptera

Marks of Identification:

- The moths are stout, light yellowish- brown. Hind wings are pale smoky white with a broad blackish outer margin
- The caterpillars are greenish with darker broken grey line along the sides of the body.
- They are 37 to 50 mm in length, when full grown.

Nature Damage:

- The caterpillars feed on chlorophyll of young leaves and skeletonise it.
- They feed voraciously on the foliage in early stage, may defoliate the plant and later they feed on flowers and pods.
- Thus, heavy losses in yields are incurred under heavy infestation level.

Life Cycle:

- The female lay eggs singly on the tender parts of the plants or

flower buds. IP- 6 to 7 days.

- Pupate in earthen cocoons in the soil near the plants.

6. White fly (*Bemisia tabaci* Gennadius) Aleurodidae: Hemiptera

Mark of Identification:

- Nymphs and pupae: Black and round or oval. Pupae have marginal bristles.
- Adults: Small, yellow bodied insects with white wings which are densely covered with a waxy powder
- **Nature of Damage:**
- Both nymphs and adults suck the cell sap from the leaves and devitalize the plants.
- As a result of their feeding the leaves turn yellow and become curled.
- This insect spread the mosaic disease in soybean.
- Besides, they also excrete honey-dew on leaves, on which black sooty mould develops.

INTEGRATED PEST MANAGEMENT PRACTICES:

IPM is a knowledge-intensive sustainable approach for managing pests by combining compatible cultural, biological, chemical, and physical tools in a way that minimizes economic, health, and environmental risks with the help of pest scouts.

1. Cultural practices:

- Cleaning of infected stubbles followed by deep summer ploughing, optimal fertilizer application, timely sowing, proper seedbed conditions and depth of sowing, optimum seeding rate and plant population, regular scouting, rogueing and destruction of infected crop/plant parts, elimination of collateral/alternate and reservoir hosts, crop rotation and intercropping, cultivation of soybean in rainy season only and avoidance of mono varietal culture.

2. Mechanical Practices:

- Collection and destruction of girdle beetle infested plant parts, egg masses and gregariously feeding larvae of hairy caterpillar and tobacco caterpillar should be done.
- Rogueing of *Sclerotium* affected seedlings and yellow mosaic affected plants should be undertaken.
- Erection of bird perches @ 10-12/ha.
- Installation of pheromone traps for monitoring incidence of *S. litura* and *H. armigera*.
- Use of Castor as trap crop for tobacco caterpillar and Dhaincha for girdle beetle.

3. Biological Control:

- Conserve spiders, coccinellid beetles, tachinid fly, praying mantids, dragon fly, damsel fly, *Chrysoperla* and meadow grass hoppers through minimum use of broad spectrum pesticides, so as to exploit maximum potential of bio-control fauna.
- Release *Telenomus remus* @ 50000/ha against *S. litura*.
- Spray Bacillus thuringiensis var. kurstaki, Serotype H-39, 3b, Strain Z-52 @ 0.75 to 1.0 kg/ha for the management of semilooper complex (*Chrysodeixis acuta*, *Gessonia gemma*, *Diachrysia orichalcea* and defoliators).
- Spray SlNPV @ 250 LE/ha
- Spray of NSKE @ 5% for management of early stage larvae and sucking pest.

4. Chemical Control:

To use any one of the following insecticides with recommended doses:

Insect	Insecticides and dose
Stem fly (Melanogromyza sojae)	Thiamethoxam 30% FS @ 10 Kg/hg Chlorantraniliprole 18.5% SC @ 150 ml/ha. Dimethoate 0.03% 30 EC
Defoliators (*Spodoptera litura*) (*Helicoverpa armigera*, Semiloopers)	Chlorantraniliprole 18.5% SC @ 150 ml/ha. Indoxacarb 15.8% EC @ 333 ml/ha Bacillus thuringiensis var. kurstaki, Serotype H-39, 3b, Strain Z-52 (Bt) @ 0.75 to 1.0 Kg/ha Quinalphos 25 EC @ 1000 ml/ha
Girdle beetle (*Obereopsis*	Chlorantraniliprole 18.5% SC @ 150 ml/ha.

brevis)	
White fly (*Bemisia tabaci*)	Dimethoate 30 EC @ 2ml /lit at the crop age of 35-40 days and repeat after 15 days if needed.

Conclusion

Soybean is highly vulnerable to a range of insect pests such as tobacco leaf eating caterpillar *Spodoptera litura,* Girdle beetle (*Oberea brevis*), Stem fly (*Melanagromyza sojae*), Whitefly (*Bemisia tabaci*) and Green semilooper (*Chrysodeixis acuta*). Correct identification of each pest at its early stage is crucial, as misidentification can lead to ineffective control measures and economic losses. Integrated Pest Management (IPM) offers a sustainable and eco-friendly approach to control these pests. By integrating these measures, farmers can minimize yield losses, reduce pesticide dependency, preserve beneficial organisms, and maintain environmental safety. Successful pest management in soybean depends on timely identification, monitoring pest population against ETL (Economic Threshold Level), and adopting preventive measures rather than relying solely on curative chemical control. The information generated in present study would be helpful in developing efficient pest management strategies against insect of soybean crop for increased production efficiency, profit besides safety to the environment.

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EXPLOITING PLANT IMMUNITY-ASSOCIATED GENE NETWORKS FOR DURABLE DISEASE RESISTANCE: INTEGRATING CRISPR-BASED EDITING WITH GENOMIC SELECTION IN CLIMATE-RESILIENT CROPS

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Abstract

Climate change, coupled with the emergence of novel plant pathogens, poses significant threats to global food security, thereby necessitating the adoption of innovative methodologies aimed at cultivating crops endowed with enduring disease resistance and resilience to climatic variations. This review delineates the synthesis of CRISPR-based genome editing techniques alongside genomic selection (GS) as a groundbreaking strategy to harness plant immunity-associated gene networks for the enhancement of sustainable agricultural practices. We investigate how CRISPR facilitates the precise modulation of critical immune components, encompassing pathogen recognition receptors (PRRs), nucleotide-binding leucine-rich repeat (NLR) proteins, and defense signaling pathways, while concurrently minimizing any potential yield compromises. Simultaneously, GS expedites the breeding process through the prediction and accumulation of polygenic resistance traits in conjunction with alleles that confer climate adaptability. Collectively, these technologies present a synergistic paradigm: CRISPR contributes targeted genetic modifications, whereas GS refines the underlying genetics to optimize agronomic performance. We underscore successful implementations in staple crops, address inherent challenges (such as off-target effects, pathogen evolution, and regulatory obstacles), and propose solutions that leverage emerging methodologies, including single-cell omics, AI-driven breeding techniques, and nanoparticle-based delivery systems. By aligning precision genome editing with sophisticated breeding analytics, this integrated methodology holds the potential to revolutionize the creation of next-generation crops capable of enduring integrated biotic and abiotic stresses. The realization of these potential mandates international collaboration to democratize

technological advancements, synchronize regulatory frameworks, and prioritize solutions that center on the needs of farmers—imperative measures toward the establishment of climate-resilient agricultural systems and the assurance of global food security.

Key words: CRISPR, genomic selection, plant immunity, disease resistance, climate resilience

1.1 Introduction

Plant pathogens present a considerable challenge to global food security, particularly in the context of escalating climate change, which intensifies the evolution and dissemination of pathogens. Conventional breeding and chemical interventions have demonstrated partial efficacy but frequently lack sustainability, as pathogens swiftly adapt to these measures. To effectively confront this issue, a revolutionary methodology is required, one that capitalizes on the inherent capabilities of plant immune systems while integrating advanced biotechnological innovations. Recent progress in molecular biology and genomics has elucidated intricate gene networks associated with plant immunity, encompassing pathogen recognition (e.g., NLR genes), signaling pathways (e.g., MAP kinases), and defensive responses (e.g., PR proteins). Nevertheless, the application of these genes in crops via traditional breeding methods is protracted and often results in compromises between yield and stress resilience. CRISPR-based genome editing offers a precise and expedient approach to modify these immune networks, facilitating the development of crops endowed with enhanced and sustainable disease resistance. Concurrently, genomic selection (GS) accelerates breeding efforts by predicting phenotypic traits from genetic markers, thereby enabling the swift transfer of advantageous alleles.

The amalgamation of CRISPR editing with GS engenders a synergistic strategy; CRISPR can introduce or refine critical resistance genes, while GS guarantees that these modifications are integrated with traits conducive to climate resilience, such as drought resistance and thermal adaptability. This chapter investigates the potential of utilizing plant immunity gene networks through CRISPR-Cas9-mediated editing and genomic selection to engineer next-generation, disease-resistant crops. We analyze essential gene networks regulating plant immunity, CRISPR methodologies for enhancing disease resistance without incurring fitness detriments, the function of genomic selection in consolidating beneficial alleles for climate resilience, and prospective trajectories for the integration of these technologies into sustainable crop enhancement. By merging precise genome editing with sophisticated breeding techniques, this integrated strategy presents significant promise for the cultivation of crops

capable of withstanding both biotic and abiotic stresses, thus bolstering food security in the face of climate change.

2.1 Plant Immunity-Associated Gene Networks: Foundations for Disease Resistance

Plants exhibit complex immune-related gene networks that underpin their capacity for disease resistance, primarily through pattern-triggered immunity (PTI) facilitated by pathogen recognition receptors (PRRs) that identify microbial molecular patterns, and effector-triggered immunity (ETI) involving nucleotide-binding leucine-rich repeat (NLR) proteins that detect pathogen effectors. Both mechanisms elicit defense responses via signaling hormones such as salicylic acid and jasmonic acid, transcriptional reprogramming through WRKY and MYB transcription factors, and the synthesis of antimicrobial metabolites. Nonetheless, these defensive strategies frequently result in trade-offs between growth and defense, wherein the continuous activation of defense responses diminishes yield potential, underscoring the necessity for precise genetic modifications to enhance immunity without detracting from productivity.

Leveraging the natural allelic variation found in wild relatives, in conjunction with sophisticated genome editing technologies such as CRISPR-Cas9 for the alteration of significant immune regulators (e.g., susceptibility genes, NLRs), and employing genomic selection to accumulate advantageous alleles, presents a promising framework for the development of crops endowed with durable, broad-spectrum resistance, while simultaneously preserving climate resilience and agronomic efficacy. The integration of these methodologies necessitates a comprehensive understanding of immune network dynamics, pathogen co-evolution, and energy allocation costs to engineer next-generation crops that achieve a balance between robust disease resistance and optimal growth under fluctuating environmental circumstances.

3.1. CRISPR-Based Genome Editing for Precision Modulation of Immune Pathways

The advent of CRISPR-Cas genome editing has fundamentally transformed our capacity to meticulously engineer plant immune systems by facilitating targeted alterations of pivotal genes associated with pathogen recognition, signal transduction, and defensive responses. By disrupting susceptibility (S) genes such as OsSWEET14 in rice to impart resistance against bacterial blight or by creating novel recognition specificities in NLR immune receptors, CRISPR permits direct modification of plant-pathogen interactions without the introduction of exogenous DNA. This innovative technology further allows for the precise calibration of immune responses through targeted promoter alterations or epigenetic modifications to enhance defense gene

expression patterns, thereby mitigating the yield penalties frequently linked to constitutive immunity. Moreover, multiplexed CRISPR systems empower the concurrent editing of multiple components within immune signaling networks, enabling researchers to stack resistance genes or reconfigure hormonal signaling interactions between salicylic acid and jasmonic acid pathways. When integrated with base/prime editing technologies, CRISPR platforms have the potential to generate allelic variants of immune receptors that broaden resistance spectra while preserving intrinsic regulatory patterns. These precision editing methodologies are particularly potent when guided by structural biology insights into pathogen effector targets and immune receptor activation mechanisms, facilitating the rational design of disease resistance traits. The amalgamation of CRISPR editing with high-throughput phenotyping and genomic selection expedites the advancement of crop varieties exhibiting durable, broad-spectrum resistance while maintaining indispensable agronomic traits under climate stress conditions, epitomizing a transformative strategy for sustainable crop protection.

4.1. Genomic Selection (GS) for Accelerating Breeding of Disease-Resistant Crops

By facilitating the quick detection and pyramiding of advantageous alleles across intricate immune-associated gene networks, genomic selection has become a potent technique that has the potential to completely transform the creation of disease-resistant crops. GS uses genome-wide SNP markers and sophisticated prediction algorithms to estimate breeding values for polygenic disease resistance traits, capturing both major and minor QTLs influencing immunological responses, in contrast to standard marker-assisted selection that is restricted to major-effect genes. This method efficiently addresses the growth-defense trade-off conundrum by enabling the simultaneous selection of numerous defense-related loci while preserving yield and climate resilience features, making it especially useful for breeding persistent resistance.

Through the combination of multi-omics data (metabolomics, transcriptomics) and machine learning algorithms that interpret intricate genotype-phenotype links in pathogen interactions, the predictive potential of GS models is continuously improved. Through the combination of multi-omics data (metabolomics, transcriptomics) and machine learning algorithms that interpret intricate genotype-phenotype links in pathogen interactions, the predictive potential of GS models is continuously improved. Field-based high-throughput phenotyping technologies offer accurate disease resistance scoring in real-world scenarios, which improves GS accuracy even more. When used in conjunction with CRISPR-based gene editing,

GS allows for a two-pronged approach: genomic prediction to optimise background genetics and precision modification of known resistance genes. Programs for rice blast resistance and wheat stem rust resistance have shown how this integrated framework significantly reduces breeding cycles while boosting genetic gain. By constantly updating training populations with new pathogen strains and environmental data, GS offers a dynamic tool to quickly deploy resistant types as climate change speeds up pathogen development, guaranteeing global food security.

5.1. Integrating CRISPR and Genomic Selection for Next-Generation Crops

A revolutionary approach to creating next-generation crops with long-lasting disease resistance and climate resilience is the combination of genomic selection (GS) and CRISPR-based genome editing. While GS offers a supplementary framework for optimising complicated polygenic features through genome-wide prediction models, CRISPR allows precise manipulation of important immune-related genes, such as altering NLR receptors for broader pathogen identification or knocking out susceptibility factors. Breeders can significantly speed up the breeding cycle by adopting this synergistic method to rapidly select for the best genetic backgrounds using GS and incorporate specific genetic improvements via CRISPR. For example, GS models trained on multi-environment trials guarantee that these alterations are implemented in genetic backgrounds that preserve yield and stress adaptability, whereas CRISPR can be utilised to quickly introduce novel resistance genes into elite germplasm.

Advanced breeding schemes now combine these technologies by using CRISPR to create allelic diversity at target loci, then applying GS to select progeny with the best combinations of edited traits and favorable genomic regions. Furthermore, machine learning-enhanced GS models can identify optimal gene editing targets by predicting how specific modifications will interact with the broader genetic network. This integrated paradigm is particularly powerful for stacking multiple resistance genes while avoiding linkage drag, as demonstrated in wheat (simultaneous editing of Pm genes for powdery mildew resistance) and rice (pyramiding blast resistance alleles with drought tolerance QTLs). As both technologies mature, their integration promises to overcome traditional trade-offs between precision and speed in crop improvement, enabling the development of cultivars with robust, durable disease resistance tailored to changing climates, a critical step toward sustainable agriculture in the face of global food security challenges.

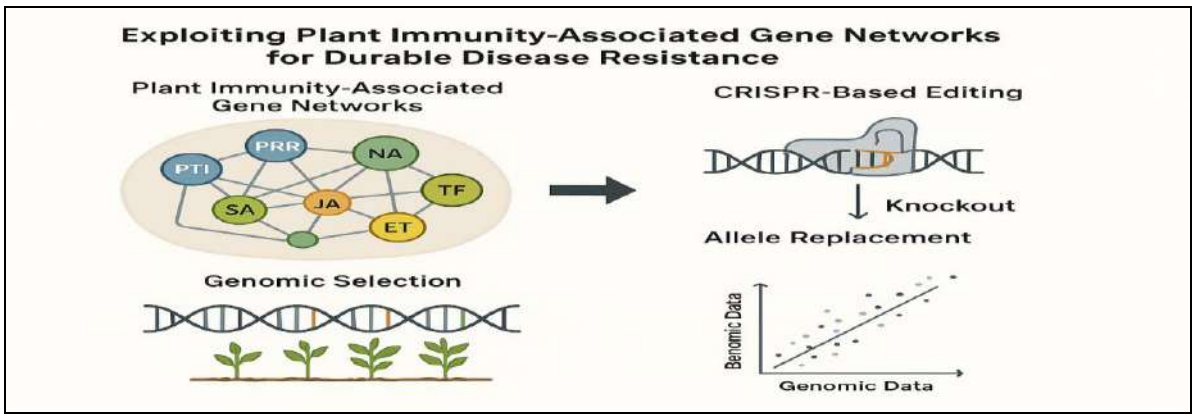

Figure: Exploiting Plant Immunity Gene Networks for Next-Generation Crop Protection

Challenges and Future Perspectives in CRISPR-GS Integrated Crop Improvement

While the integration of CRISPR and genomic selection (GS) holds tremendous potential for developing next-generation crops, several key challenges must be addressed to realize its full impact. Technical limitations persist, including off-target effects of CRISPR edits, incomplete penetrance of engineered traits, and the computational complexity of modeling gene-editing outcomes in GS predictions. Biological constraints such as pleiotropic effects of immune gene modifications and pathogen evolutionary counter-adaptations threaten the durability of engineered resistance. The regulatory landscape remains uncertain, with varying global policies on genome-edited crops creating market access barriers and stifling innovation. Additionally, socioeconomic hurdles including technology access disparities between developed and developing nations, and public perception of genome-edited foods, may slow adoption. Looking ahead, emerging technologies could overcome these challenges. Single-cell omics and spatial transcriptomics will provide unprecedented resolution of immune gene networks, enabling smarter CRISPR target selection. AI-driven predictive breeding platforms could integrate real-time pathogen surveillance data with GS models to stay ahead of evolving diseases.

Nanoparticle-based delivery systems may revolutionize CRISPR editing efficiency in difficult-to-transform crops. On the policy front, harmonized international regulations and open-source biotechnology platforms could democratize access to these technologies. Future research should prioritize multiplex editing of entire immune pathways, field validation of CRISPR-GS hybrids under climate stress, and development of bioinformatic tools that unify gene editing design with genomic prediction. As these solutions mature, the CRISPR-GS integration

paradigm could ultimately enable predictive, precision plant breeding - ushering in a new era of climate-smart crops with naturally enhanced immunity and sustainable productivity.

Conclusion

The integration of CRISPR-based genome editing and genomic selection offers a transformative pathway toward sustainable, climate-resilient agriculture by enabling precise engineering of plant immune systems while simultaneously optimizing complex trait combinations for yield and stress adaptation. To realize this potential, global efforts must prioritize democratizing these technologies through international partnerships, establishing science-based regulatory frameworks, and implementing pathogen surveillance networks to ensure durable resistance. Research should focus on developing climate-smart crop varieties through advanced multi-omics approaches and AI-driven breeding platforms, while ensuring solutions meet farmer needs through participatory programs. By aligning cutting-edge science with equitable innovation policies, this CRISPR-GS revolution can address the dual challenges of food security and climate change, ushering in a new era of precision crop improvement that reduces agriculture's environmental footprint while bolstering resilience against evolving biotic and abiotic stresses. The urgency to act is clear - strategic investments today in these integrated technologies will determine our ability to sustainably feed a growing population under increasingly challenging climatic conditions.

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NANOSELENIUM: A PARTICLE FOR REPRODUCTIVE AND PHYSIOLOGICAL BENEFITS IN FISH

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Abstract

Aquaculture is rapidly becoming a key component of global food security, with the reproductive performance and physiological health of broodstock being crucial for productivity and sustainability. In recent years, nutritional strategies have gained significance in enhancing fish health, especially with functional feed additives. Selenium, an essential trace element, plays a multifaceted role in fish physiology by supporting antioxidant defense systems, regulating reproductive hormones, strengthening immune responses, and alleviating the effects of environmental and physiological stress. Traditionally, selenium has been supplied in organic and inorganic forms, both of which have limitations regarding bioavailability and the potential for toxicity at higher concentrations. Selenium nanoparticles (SeNPs) have emerged as a promising alternative due to their improved absorption, controlled release, reduced toxicity, and enhanced physiological efficacy even at lower dosages. This seminar will explore the potential of nano-selenium in aquaculture, highlighting its advantages over conventional forms. SeNPs have shown significant improvements in fish growth rates, feed efficiency, survival, immune competence, and reproductive outcomes. Additionally, SeNPs can enhance the expression of genes associated with antioxidant defenses, stress tolerance, and hormonal regulation, offering a molecular basis for their benefits. Their ability to efficiently cross intestinal barriers and accumulate in target tissues further emphasizes their value as a strategic nutritional tool. Given its cost-effectiveness, environmental safety, and broad physiological benefits, nano-selenium represents a significant advancement in fish nutrition, especially in modern, intensive aquaculture systems that aim to improve productivity without compromising fish welfare or

environmental health.

Introduction

Aquaculture is the fastest-growing sector in the food industry, accounting for over 50% of the world's seafood production for consumption. This sector is critical in food security and economic development, making sustainable practices essential. The aquafeed industry is crucial for meeting the rising demand for aquatic animal feed. As aquaculture expands, the need for feed, representing the most significant variable cost in operations, grows. The reliance on conventional feedstuffs like fishmeal and soy raises sustainability concerns. Therefore, exploring alternative feed sources and enhancing the use of existing ingredients is important. Trace elements, such as zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), and selenium (Se), are essential for fish growth, immune function, reproduction, and stress response. Incorporating these minerals into aquafeed can improve growth performance and feed efficiency. Due to their higher bioavailability, there is increasing interest in using nano forms of trace elements. These nano elements enhance nutrient absorption and promote better physiological responses in aquatic animals. Selenium supplementation has shown significant benefits in fish diets, improving growth and immune resistance across various species, such as Asian seabass and Nile tilapia. Selenium can be included in aquafeeds in either inorganic form (e.g., selenate sodium) or organic form (e.g., hydroxy selenomethionine), contributing to better fish health and food production.

Nano-enhanced diet in aquaculture

The exploration of nanoparticles as feed additives presents new possibilities and opportunities to enhance the benefits of aquaculture feed. Nanoparticles can significantly improve the stability of proteins, promoting several biological functions such as digestion, metabolism, and nutrient uptake. They can encapsulate essential nutrients like vitamins, minerals, and fatty acids, protecting them from degradation and ensuring their targeted delivery to aquatic organisms. In addition to enhancing the durability and availability of feed components, nanoparticles can alter the physical characteristics of aquaculture feed. Even small amounts of nanomaterials can significantly improve the structural properties of aquafeed pellets. Moreover, dietary feed additives containing nanoparticles of selenium, manganese, zinc, iron, copper, and magnesium offer multiple advantages for aquatic animals compared to conventional feed formulations.

Advantages of a nano-enhanced diet

- Reduced risk of leaching into water
- Decreased dosage requirements
- Enhanced efficacy of antioxidants and preservatives
- Improved bioavailability, Preservation of chemical integrity
- Extended shelf life, Prolonged storage protection
- Stability under mechanical, thermal, and pH conditions

Selenium in fish nutrition

Selenium (Se), an essential trace mineral, is vital in physiological processes, promoting antioxidant defences and maintaining redox balance. Traditionally, fish meal has been the primary source of selenium in commercial feeds. However, the shift to alternative, primarily plant-based ingredients has led to reduced selenium content, making supplementation necessary. Recent studies have shown the positive effects of selenium on various fish species, improving growth, feed utilization, and disease resistance. Selenium ensures better fish health and secure food production. Selenium can be included in aquafeeds in inorganic (e.g., sodium selenate) or organic (e.g., hydroxy selenomethionine) forms.

Selenium dietary requirements

Selenium (Se) supplementation effects depend on dosage and chemical form. Fish need specific Se levels due to the narrow margin between its essentiality and toxicity. The European Union limits Se in fish diets to 0.1 mg/kg to 2 mg/kg based on fish type and age to prevent toxicity. Optimal Se levels vary by species, growth stages, source, environmental conditions, diet formulation, and water quality.

Forms of selenium

The absorption and metabolic pathways of selenium (Se) in fish vary by form. The main types are inorganic selenium, like sodium selenite (Na_2SeO_3), which is passively absorbed and converted to selenides; organic selenium, such as selenomethionine, absorbed as amino acids; and selenium nanoparticles (Nano-Se), which activate antioxidant gene expression. Na_2SeO_3 is slightly less toxic than Na_2SeO_4. While inorganic selenium is commonly used in fish diets, interest in Nano-Se is growing due to its higher bioavailability and lower toxicity. Nano-Se can enhance sea bream's growth and antioxidant capacity more effectively than organic or inorganic forms.

Nano-Selenium: Properties & Advantages

Nano-selenium has shown promise in mitigating stress in aquatic environments and could play a significant role in production enhancement and sustainability by reducing pollution and chemical use. Nano-Se offers advantages over traditional selenium supplementation, such as improved bioavailability and reduced toxicity. This can positively impact aquaculture product quality and health. Optimizing selenium nanoparticles in diets can improve various species' growth performance, digestibility, and antioxidant activity. Depending on species, recommended dietary dosages range from 0.15 to 4 mg/kg. Studies have shown the benefits of supplemented aquafeeds with Nano-Se in Asian seabass, Nile tilapia, common carp, European sea bass, and Pacific white leg shrimp.

Preparation of Nano selenium

Nano selenium can be prepared using chemical reduction methods, often involving a selenite salt (sodium selenite) and a reducing agent like ascorbic acid or glutathione. Stabilizers like polysorbate 20 or bovine serum albumin are also commonly used to prevent aggregation.

Preparation Methods:

- **Chemical Reduction:**

1. Reactants: Sodium selenite (Na2SeO3) is dissolved in water to create a selenite solution. A reducing agent, ascorbic acid or glutathione, is added to the solution.
2. Stabilization**:** A stabilizer, like Polysorbate 20 or bovine serum albumin, is introduced to prevent the formation of larger selenium aggregates.
3. Reaction: The solution is stirred and may be heated slightly (e.g., 60-80°C), and the reduction process occurs, leading to the formation of Nano selenium.
4. Collection: The Nano selenium particles can be collected by centrifugation, and the resulting pellet can be resuspended.

- **Biological Reduction:**

1. Biological Source: Various microorganisms (bacteria, fungi, yeasts) and plant extracts can reduce selenite to Nano selenium.
2. Reduction Process: The biological source is exposed to selenite, and the organism's metabolic activity or specific proteins/enzymes facilitate the selenite reduction.
3. Nano selenium Formation: Nano selenium particles are formed, and their size and shape can be influenced by the specific microorganism or plant extract.

- **Other Methods:**

Physical methods: Techniques like laser ablation, sonochemical methods, and microwave heating can also synthesize nano selenium.

Hydrothermal synthesis: This method involves using high temperatures and pressures to induce the chemical reduction of selenite.

Effect of Nano-Se as a growth enhancer

Se, as a crucial constituent of deiodinases, participates in thyroid hormone metabolism by catalyzing the conversion of T4 to T3, which is the active type of thyroid hormones and subsequently raises the transcripts of growth-related genes, including growth hormone (GH) and IGF-I. Seabream fed plant-protein diets supplemented with Nano-Se at 2–4 mg/Kg exhibited improved growth and feed utilization. Nutritional Nano-Se enhances growth performance in fish by stimulating the thyroid hormone-growth hormone axis.

Using nano-selenium supplements for stress resistance

Oxidative stress occurs when there is an imbalance in reactive oxygen species (ROS) production and removal, often due to pathogenic invaders. Excess ROS can damage cell membrane lipids and RNA, leading to lipid peroxidation, measured by malondialdehyde (MDA) levels. Selenium acts as an antioxidant by promoting glutathione peroxidase (GPx) production to combat oxidative stress. Dietary selenium at 1.0 mg/kg has been shown to enhance immune response and antioxidant defences in Chinese mitten crabs (*Eriocheir sinensis*) under nitrite stress and improve growth and antioxidant activity in juvenile rainbow trout under chronic stress.

Using nano-selenium supplements as an antioxidant system

Selenium is an antioxidant element, an extra-effective antioxidant, and plays an important role in the antioxidant defence mechanism of fish. It protects the cell membrane from oxidative damage through regulating glutathione peroxidase (GPX) activity. Selenium can decompose and clear peroxides, thus preventing the accumulation of reactive oxygen species and free radicals such as hydrogen peroxide (H_2O_2) in the body tissues. A study reported that using Se3 mg/kg dietary nano in a basal diet can enhance the antioxidant capacity of various fish species. Previous studies reported that dietary Se can affect an antioxidant gene in *Nibea color*. A similar study reported that Se supplement can increase the antioxidant SOD, CAT, and GPx activity in Rainbow Trout and juvenile white sturgeon.

Effects of Nano-Se on Immunity in Fish

Biogenic nano selenium (Nano-Se) supplements have been found to upregulate pro-inflammatory cytokines and enhance immune factors in fish. They improve the stability of blood cells by altering transferrin receptors in hematopoietic tissues and provide antioxidant protection against hemolysis. One study showed that Nano-Se supplementation significantly improved Nile tilapia's growth, hematological indices, and immune parameters. Furthermore, selenium boosts fish immunity by increasing lymphocyte protein synthesis and the activity of immune cells.

Conclusion

Environmental factors like water quality and nutrition are crucial for optimal fish growth and reproduction. Selenium is key in supporting immunity, growth, and antioxidant defense. Due to their enhanced bioavailability, nano-selenium (Nano Se) supplements offer a cost-effective, nontoxic, and environmentally friendly way to improve fish health. Research shows that ano Se boosts reproductive performance, increases selenium levels in key organs, and elevates hormones like testosterone and progesterone. Additionally, it enhances immunity and disease resistance, making it an effective supplement for improving both reproductive and physiological benefits in fish.

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BENEFICIAL MICROORGANISMS IN AGRICULTURE

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1. Introduction

"Freedom from want of food is a basic freedom without which no other freedom can be fully enjoyed." These words were spoken in 1943 by Frank L. McDougall, the Australian agricultural economist whose vision helped lay the foundation for the Food and Agriculture Organization of the United Nations. At the height of the Second World War, when millions were threatened by hunger, leaders gathered in Hot Springs, Virginia, to confront the urgent task of rebuilding food systems and restoring hope.

Today, although the world has advanced technologically, the challenge of ensuring food security remains as critical as ever. The emergence of chemical fertilizers and pesticides boost crop yields, but their overuse comes at a cost. According to the Food and Agriculture Organization (FAO), global fertilizer consumption has increased nearly eightfold since the 1960s. And indeed FAO states that 30–50% of the world's food production is directly linked to the use of synthetic fertilizers in which cereal production increased globally from about 800 million tonnes in 1960 to over 2.9 billion tonnes in 2025. However, fertilizers and pesticides lead to unwanted consequences such as soil degradation, water pollution, greenhouse gas emissions, reduced efficiency and agricultural non-point source pollution.

Particularly, excessive use of pesticides and fertilizers infiuences the safety of the ecological environment and agricultural production, and further threatens human health and sustainable agricultural development. With finite resources, the pressure of the growing global population, and human physical and mental health, we need a plan to stimulate action in areas of critical importance for agriculture. In September 2015, the United Nations launched the

Sustainable Development Goals. To achieve this goal, there is an urgent need to harness the multiple beneficial interactions that occur between plants and microorganisms. The uniqueness of microorganisms and their often unpredictable nature and biosynthetic capabilities, given a specific set of environmental and cultural conditions, has made them likely candidates for solving particularly difficult problems in the life sciences and other fields as well. The uniqueness of microorganisms and their often unpredictable nature and biosynthetic capabilities, given a specific set of environmental and cultural conditions, has made them likely candidates for solving particularly difficult problems in the life sciences and other fields as well.

2. EFFECTIVE MICROORGANISMS AND ITS APPLICATION

Effective microorganisms (EM) is developed by Dr. Teruo Higa, a Japanese scientist who developed a mixed culture of beneficial microbes aimed at improving soil health and agricultural productivity. Effective microorganisms are a mixed culture of beneficial and naturally occurring microorganisms, such as species of photosynthetic bacteria (Rhodopseudomonas palustris and Rhodobacter sphaeroides), lactobacilli (Lactobacillus plantarum, L. casei, and Streptococcus lactis), yeasts (Saccharomyces spp.), and Actinomycetes (Streptomyces spp.). These beneficial microorganisms improve crop growth and yield by increasing photosynthesis, producing bioactive substances such as hormones and enzymes, controlling soil diseases, and accelerating decomposition of lignin materials in the soil. Experiments conducted on various agricultural crops in different parts of the world have shown good prospects for the practical application of these beneficial microorganisms in improving crop yield and soil fertility.

2.1 Theories of Effective Microorganisms

The Dominance Principle

According to Prof. Higa, microorganisms in any environment can be broadly grouped into three categories: beneficial (regenerative), harmful (degenerative), and opportunistic microbes that can act either way depending on conditions. The Dominance Principle states that the overall behavior of the microbial community is determined by which group dominates. If beneficial microbes are in greater numbers, they create conditions that favor regeneration, nutrient cycling, and plant health. In contrast, if harmful microbes dominate, the environment shifts toward decay, disease, and loss of fertility. Opportunistic microbes simply follow whichever group is stronger, aligning with either regeneration or degeneration.

The practical implication of this principle is that by deliberately introducing and supporting populations of beneficial microorganisms, such as those found in EM formulations, it is possible to guide the entire microbial community in soil, water, or even living organisms toward a healthier, regenerative state.

Organic Energy Theory

The Organic Energy Theory explains that Effective Microorganisms (EM) help turn organic matter into simple nutrients that plants can use easily. Normally, organic residues may rot and produce harmful byproducts, but when EM is applied, they go through a fermentation process instead. In this process, lactic acid bacteria and other useful microbes break down the material into amino acids, sugars, and other compounds that plants can absorb directly. A study by Kinjo in 1990 showed that organic matter treated with EM had much higher levels of amino acids compared to untreated matter, which supports the idea that EM improves the nutritional quality of soil inputs. This fermentation not only provides plants with ready energy but also reduces bad odors, prevents harmful decomposition, and promotes healthier soil conditions.

Photosynthetic and Nitrogen Fixing Theory

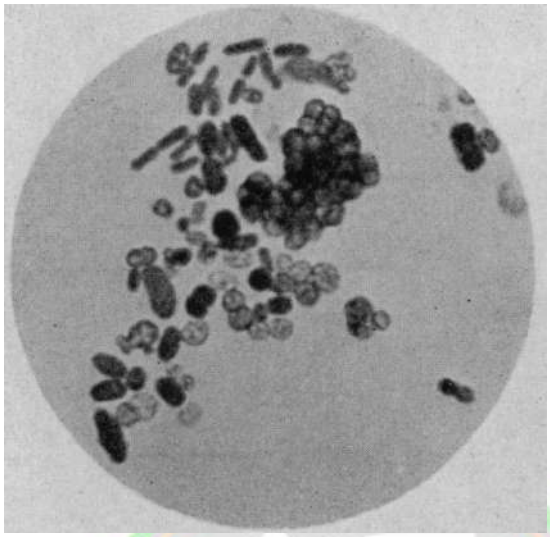
This theory links EM application with the promotion of photosynthetic and nitrogen-fixing bacteria in soils and plant surfaces. These microbes can capture solar energy and carbon dioxide, producing bioactive substances that support plant growth, while some also possess the ability to fix atmospheric nitrogen and convert it into biologically available forms. Higa suggested that this process could improve photosynthetic efficiency in plants, enhance nitrogen availability and crops grown under EM treatment may show higher vitamin content, sugar concentration, and overall vigor.

3. TYPES AND FUNCTIONS OF BENEFICIAL MICROORGANISMS

3.1. Nitrogen-Fixing Bacteria

The potential of nitrogen-fixing (NF) bacteria to form a symbiotic relationship with leguminous plants and fix atmospheric nitrogen has been exploited in the field to meet the nitrogen requirement of the latter. This phenomenon provides an alternative to the use of the nitrogenous fertiliser whose excessive and imbalanced use over the decades has contributed to green house emission (N2O) and underground water leaching. A wide diversity of nitrogen-fixing bacterial species belonging to most phyla of the Bacteria domain have the capacity to colonize the rhizosphere and to interact with plants.The most well-known are Rhizobium species,

which form nodules on legume roots. Other free-living nitrogen fixers, like Azotobacter and Azospirillum, also enrich soil nitrogen.

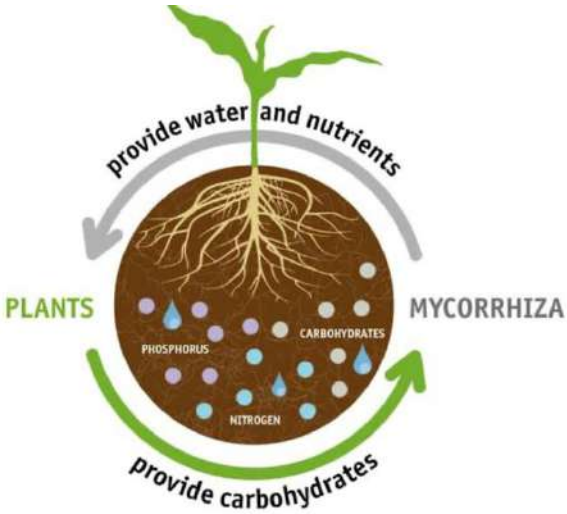


3.2 Phosphate-Solubilizing Microbes

Phosphorous -solubilizing microorganisms (PSMs) when applied in appropriate numbers into the rhizosphere help the plant by supplementing P in plant-utilizable form by several mechanisms. In addition, few PSMs also possess added features as plant growth-promoting rhizobacteria (PGPR) and biocontrol agents conferring protection from phytopathogens. Improvement in soil characters by PSMs is an added advantage.Bacillus, Pseudomonas, and certain fungi like Aspergillus secrete organic acids to dissolve phosphorus and make it available to plants which improve phosphorous nutrition and promote stronger roots.

3.3 Mycorrhizal Fungi

Symbiotic associations between arbuscular mycorrhizal fungi and plant roots are widespread in the natural environment and can provide a range of benefits to the host plant. These include improved nutrition, enhanced resistance to soil-borne pests and disease, improved resistance to drought, tolerance of heavy metals and better soil structure. Many agricultural crops are mycorrhizal and there is widespread if equivocal evidence that crop plants benefit from the arbuscular mycorrhizal (AM) association in the same way.



3.4 Plant Growth-Promoting Rhizobacteria (PGPR)

Plant growth-promoting rhizobacteria (PGPR) are naturally occurring soil bacteria that aggressively colonize plant roots and benefit plants by providing growth promotion. Inoculation of crop plants with certain strains of PGPR at an early stage of development improves biomass production through direct effects on root and shoots growth. PGPR are reported to influence the growth, yield, and nutrient uptake by an array of mechanisms. They help in increasing nitrogen fixation in legumes, help in promoting free-living nitrogen-fixing bacteria, increase supply of other nutrients, such as phosphorus, sulphur, iron and copper, produce plant hormones, enhance other beneficial bacteria or fungi, control fungal and bacterial diseases and help in controlling insect pests. There has been much research interest in PGPR and there is now an increasing number of PGPR being commercialized for various crops.

Conclusion

Beneficial microorganisms are fundamental to sustainable agriculture and global food security. Nitrogen-fixing bacteria, such as Rhizobium and Azospirillum, contribute between 50–300 kg N/ha/year, reducing the need for synthetic nitrogen fertilizers, which account for approximately 1.4% of global greenhouse gas emissions. Phosphate-solubilizing bacteria can increase available phosphorus in soils by 20–60%, improving root development and yield. Mycorrhizal fungi are known to enhance phosphorus and micronutrient uptake by up to 50%, and improve plant water relations, leading to yield increases of 10–30% in cereals and legumes. Biocontrol agents like Trichoderma spp. and Pseudomonas fluorescens suppress soil-borne pathogens, reducing crop losses by 20–40% without harmful chemicals.

According to the Food and Agriculture Organization (FAO), adopting microbial biofertilizers and biopesticides could sustainably raise productivity by 20–30%, while decreasing input costs by 15–20%. As the global population is projected to reach 9.7 billion by 2050, leveraging beneficial microorganisms is a scientifically proven strategy to enhance yields, maintain soil health, and reduce environmental impacts—key pillars of achieving lasting food security.

In the future, beneficial microorganisms will become even more central to agriculture and food security. Advances in microbial biotechnology, such as precision inoculants, microbial consortia, and bioformulations, are expected to increase crop yields by 30–40%. Emerging research on plant microbiomes and next-generation sequencing is enabling scientists to identify and harness specific strains that promote stress tolerance, nutrient efficiency, and disease resistance. By 2030, the global biofertilizer market is projected to exceed USD 5 billion, reflecting their growing adoption. Integrating beneficial microbes into climate-smart agriculture offers a sustainable way to feed an estimated 9–10 billion people by 2050, restore degraded soils, and mitigate greenhouse gas emissions. Therefore, investing in microbial technologies and farmer education will be critical to shaping a resilient, productive, and environmentally sustainable food system.

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AMERICAN FOUL BROOD: A THREAT TO BEEKEEPING

Article ID: AG-V05-I08-120

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Introduction

American foulbrood (AFB) is a most destructive bacterial disease of honey bee brood caused by the spore forming bacterium *Paenibacillus larvae*. It is not a stress related disease and can infect the strongest to the weakest colony in an apiary. Young honeybee larvae become infected by ingesting as few as ten P. larvae spores in contaminated food (Brødsgaard et al., 1998; Hitchcock et al., 1979). The spores then ger minate and proliferate in the midgut, invade the larval tissue and kill the host larva (Genersch et al., 2005; Yue et al., 2008).Infected brood usually die at the pre- pupal or pupal stage. Heavy infections can affect most of the brood, severely weakening the colony and eventually killing it. The disease is not able to be cured, meaning that destruction of infected colonies and hives or irradiation of infected material is the only way to manage AFB. Although AFB is not highly contagious, bacterial spores can easily be spread between hives and apiaries through beekeeping practices such as through the exchange of equipment and movement of infected combs. Adult bees are not affected by AFB but can spread spores within and between infected and clean hives through robbing and drifting. AFB spores can remain viable for over 50 years and are very resistant to freezing and high temperatures. Therefore, the only way to manage the disease is to stop infections from occurring through adopting beekeeping best management practices, and if an AFB outbreak does occur, quickly dealing with it before additional colonies become infected

History

Until 1906 American foulbrood was not differentiated from European foulbrood, and the condition was simply referred to as foulbrood. Thereafter, the terms European and American were used to distinguish the diseases. However, the designations do not refer to the geographical distributions but to the areas where they were first investigated scientifically. In 1907, it was demonstrated conclusively that the bacterium *Bacillus larvae* was the cause of American foulbrood disease by fulfilling Koch's Postulates.The geographical origin of AFB is unknown, but it is found almost worldwide.

Distribution

It is widely distributed in North America, including the United States and Canada, and is present throughout Europe in countries such as the United Kingdom, Germany, France, Spain, and Italy. In Asia, it has been reported in China, India, Pakistan, Japan, and parts of the Middle East. The disease is also common in Australia and New Zealand, where strict monitoring and control measures are enforced. In Africa, it has been detected in South Africa and several other countries, while in South America it is found in Argentina, Brazil, Chile, and surrounding regions.

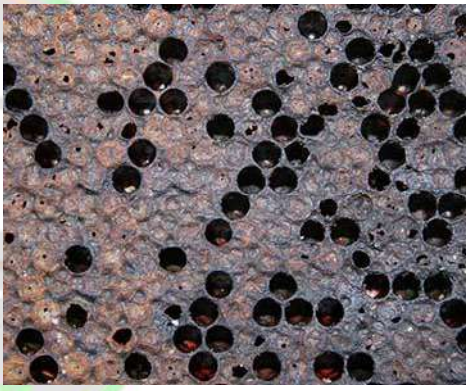
MORPHOLOGY OF PATHOGEN:

CAUSAL ORGANISM: *Paenibacillus larvae*

The bacterium is a rather fastidious, facultative anaerobe (at least for growth on artificial media), Gram-positive and catalase negative. The vegetative rods are motile and occur singly or in chains, reaching lengths of 2.5–5 μm29. A key characteristic of P. larvae is its ability to form endospores. These spores are highly resistant to environmental conditions and are the primary means of transmission and survival of the bacteria. The spores are oval-shaped, with a width of approximately 0.6 μm and a length of 1.3 μm.

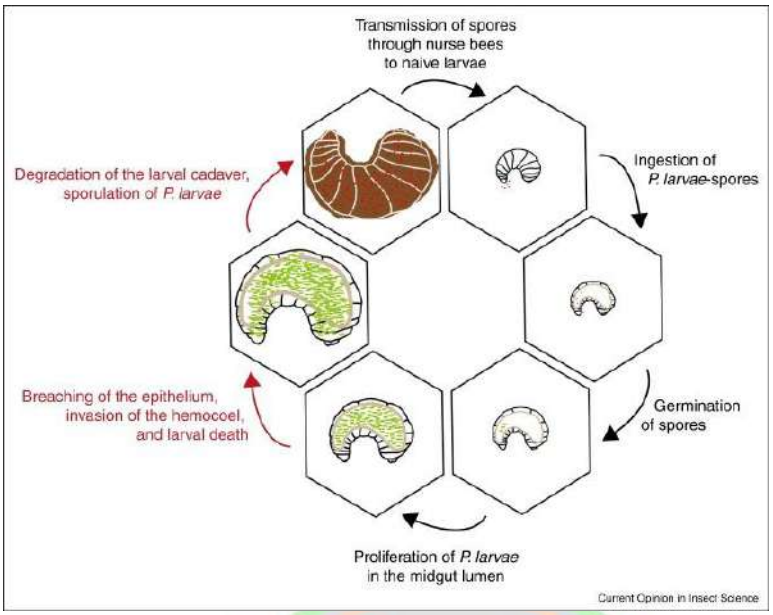
SYMPTOMS

Larvae and pupae were decayed to a brownish, viscous mass which can be drawn out with a matchstick to a long thread that may snap back if pulled too far. The decaying brood has a foul odour and dries into scales. The scales adhere tightly to the cell walls and bees can remove them only with difficulty. Dead pupae lie flat in the bottom of the cells and the remnants of their tongues extend upward. Not infrequently the remains of one or more legs protrude upward, too. As the infection proceeds, the larval remains degrade to a brownish semi-fluid glue-like mass emitting a characteristic foul odour. This 'ropy' mass and foul odour are the primary symptom for the diagnosis of AFB in the bee hive .The remains of the larva finally form a hard scale in the bottom of the cell that contains billions of extremely tenacious bacterial spores that drive the transmission of this disease within and between colonies (Lindström et al., 2008a, 2008b).



MODE OF SPREAD:

Nurse bees feed contaminated food to larvae, introducing spores into the brood .Spores are spread through contaminated honey, pollen, and hive tools inside the same hive.**Robbing-** Healthy bees rob honey from infected weak colonies and carry spores back to their hives. **Drifting -** Worker bees or drones accidentally enter neighboring colonies, transferring spores. Use of contaminated hive tools, frames, boxes, or extracting equipment. Transfer of combs or brood from infected colonies to healthy ones. Buying or exchanging bees, queens, or nucleus colonies from infected sources. Spores in honey, pollen, or wax can contaminate feeding supplements or equipment .Some spread occurs through bee predators or scavengers, though this is minor compared to direct bee-to-bee transfer.



DIAGNOSIS OF AFB:

Ropy test:

- Since larval remains of AFB-infected brood are elastic, a common field diagnostic is to pull the remains out of the cell with a toothpick or small twig.
- If the remains are elastic and "rope" out of the cell an inch or two, it is likely AFB rather than another brood disease.

Holst milk test:

- This is a simple procedure that can be accomplished in most beekeeping operations.
- Place a suspect scale or smear of a diseased larva in a glass vial containing 4 ml of 1% powdered skim milk.
- Place the tube in a warm place (preferably at 37 ºC).
- If AFB is present, the suspension should be clear in 10-20 minutes, since P. larvae spores produce proteolytic enzymes

MANAGEMENT:

- Terramycin (oxytetracycline) is the only drug approved for use against American Foul Brood.
- When present in the food given to susceptible larvae this antibiotic is effective in preventing germination of AFB spores.
- The bees are then able to develop and mature normally.

- Terramycin will not kill the spores and is not a means for sterilizing either the bees or the equipment.
- If a colony contains AFB spores and is maintained in a healthy condition through treatment with terramycin, the disease will recur when the drug treatment is discontinued.

Conclusion

American foulbrood (AFB) remains one of the most devastating bacterial diseases affecting honey bee colonies worldwide. Caused by *Paenibacillus larvae,* it destroys brood at the most vulnerable stages and weakens or kills entire colonies if left unchecked. The persistence of its spores, which can survive for decades under harsh conditions, makes eradication extremely difficult. While antibiotics such as oxytetracycline can suppress the disease, they cannot eliminate the spores, meaning outbreaks often reoccur once treatment is discontinued. Therefore, strict preventive measures, careful hive management, and rapid destruction of infected colonies are essential to safeguard beekeeping operations. Effective control of AFB not only protects honey production but also ensures the sustainability of pollination services vital for global agriculture.

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SOIL HEALTH AND CARBON SEQUESTRATION: A KEY TO CLIMATE-RESILIENT FARMING

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Abstract

Climate change is reshaping agriculture across the globe, threatening food security, soil fertility, and farm livelihoods. Among the many solutions, improving soil health and enhancing carbon sequestration have emerged as crucial strategies for climate-resilient farming. Healthy soils not only sustain crop productivity but also act as carbon sinks, reducing greenhouse gas emissions. This article explores the significance of soil health, the science of carbon sequestration, practical on-farm methods to enhance soil carbon, and the challenges and opportunities ahead.

Introduction

Cracked fields, fallen crops, dry wells, and the tear-filled eyes of farmers paint a grim picture across Assam. A 42% rainfall deficit this year has left vast tracts of land parched, serving as a reminder that climate change is no longer a distant threat but a pressing reality. Five districts have already been declared drought-hit, while more than half of the state is in drought-like conditions.

While the immediate cause is erratic rainfall, the long-term solution may lie beneath our feet — in the soil itself. Healthy soils that store carbon can act as natural buffers against climate change. By improving soil health and enhancing carbon sequestration, farmers can build resilience and turn soils into carbon sinks rather than sources. This article explores the role of soil health and carbon sequestration in ensuring climate-resilient farming.

Soil Health and Its Importance

Soil health refers to the capacity of soil to perform essential functions — supporting plant and animal productivity, cycling nutrients, storing water, and sustaining microbial life.

Healthy soil is a living system that underpins both agriculture and the environment. When soils are rich in organic matter, they naturally supply crops with nutrients, build stronger roots, and improve harvests. They act like sponges, storing water during dry spells and reducing runoff during heavy rains, thus preventing erosion and providing steady moisture. At the same time, billions of soil organisms recycle organic matter into nutrients, ensuring continuous fertility.

In contrast, degraded soils leak carbon back into the atmosphere, adding to greenhouse gases and worsening climate change. Their weakened structure makes them prone to erosion, drought, and floods, creating a vicious cycle where soil degradation and climate change reinforce each other.

Carbon Sequestration in Agriculture

Carbon sequestration is the process of capturing atmospheric carbon dioxide (CO_2) and storing it in soils and vegetation. In agriculture, this mainly occurs when plants absorb CO_2 during photosynthesis and return it to the soil through roots, crop residues, and organic amendments, building up **soil organic carbon (SOC)**. Healthy soils with more SOC act as natural carbon sinks while supporting higher productivity.

There are different types of sequestration: **biological sequestration** (in soils, trees, crops, and grasslands), **geological sequestration** (storage in deep rock formations), **oceanic sequestration** (absorption by oceans), and **technological sequestration** (carbon capture and storage using industry). Among these, biological sequestration in agricultural soils is the most practical for farmers.

Its importance lies in both environmental and economic benefits. By reducing greenhouse gases, it helps mitigate climate change. At the same time, carbon-rich soils improve fertility, enhance water-holding capacity, prevent erosion, and support microbial biodiversity. Farmers also stand to gain economically through reduced input costs and potential earnings from carbon credit markets. Globally, improved soil carbon management could offset **5–10% of annual greenhouse gas emissions**, making it one of the most cost-effective climate solutions

Practice	**How It Works**	**Carbon Sequestration Potential**
Conservation/Zero Tillage	Reduces soil disturbance, prevents carbon loss	0.2 – 0.5 t C/ha/year

Practice	How It Works	Carbon Sequestration Potential
Cover Cropping (Legumes, Grasses)	Adds biomass & organic matter to soil	0.3 – 0.6 t C/ha/year
Agroforestry	Trees store carbon in biomass and soil	1 – 3 t C/ha/year
Organic Amendments (Compost, Manure, Biochar)	Increases soil organic carbon & microbial activity	0.4 – 1.2 t C/ha/year
Crop Rotation with Legumes	Fixes nitrogen, improves soil carbon inputs	0.2 – 0.4 t C/ha/year
Improved Pasture/Grazing Management	Enhances root biomass & reduces soil degradation	0.5 – 1.0 t C/ha/year

Practices and Benefits of soil Sequestration

Farmers can adopt a range of practices that restore soil health and capture carbon. Conservation tillage reduces soil disturbance, while cover cropping and crop rotation add organic matter and promote continuous root growth. Applying compost, manure, and biochar further enriches soils, with biochar offering long-term carbon storage. Agroforestry integrates trees with crops and livestock, storing carbon above and below ground while providing timber and fodder. Perennial crops and improved grazing systems enhance root biomass, while integrated nutrient management and water conservation measures safeguard soil carbon already in place.

These practices yield multiple benefits. By building organic matter, soils become more fertile, reducing dependence on chemical fertilizers and improving yields. Carbon-rich soils act as sponges, holding more water during droughts and preventing erosion during heavy rains. Stronger soils also support microbial life that naturally suppresses pests and diseases. Beyond ecological gains, these practices help offset agricultural greenhouse gas emissions and open doors for farmers to participate in **carbon credit markets**, creating additional income streams. In short, carbon sequestration not only mitigates climate change but also strengthens farm productivity and resilienc

Challenges and Limitations

Despite its promise, soil carbon sequestration faces several hurdles. Benefits take years to become visible, discouraging farmers who need immediate returns. Measuring soil carbon is technically complex and costly, especially in smallholder systems. Many farmers lack awareness of carbon-friendly practices, while policy incentives remain limited. Moreover, soils have a finite capacity to store carbon, and poor management practices like overgrazing or excessive tillage can quickly undo progress. Addressing these challenges requires stronger policies, technical support, and long-term commitment.

Policy and Farmer-Level Adaptation

Scaling up soil carbon sequestration requires strong policies and farmer participation. Governments can encourage adoption through soil health cards, subsidies for organic inputs, crop insurance benefits, and incentives for conservation practices. Programs like the **National Mission for Sustainable Agriculture (NMSA)** in India provide frameworks for climate-smart farming, while international initiatives such as **"4 per 1000"**, which aims to increase global soil carbon by 0.4% annually, highlight its global importance.

Carbon credit markets present new opportunities by rewarding farmers for storing carbon, turning sustainable practices into income sources. At the community level, **Farmer Producer Organizations (FPOs)** can spread awareness, pool resources, and connect farmers to these markets. Digital tools such as soil mapping, remote sensing, and AI-based monitoring can also make carbon tracking more accurate and accessible. Together, these measures can transform carbon sequestration from a scientific idea into a farmer-driven solution.

Conclusion

Soil health and carbon sequestration offer a practical, science-based solution to the dual challenge of climate change and agricultural sustainability. By adopting practices that enrich organic matter and lock carbon into soils, farmers can secure higher productivity, greater resilience, and a cleaner environment. Though challenges exist, supportive policies, innovative technologies, and farmer participation can unlock the full potential of soil carbon.

As agriculture faces rising climate threats, the soil beneath our feet may hold the most powerful answer. Building climate-resilient farming begins with nurturing healthy, carbon-rich soils — the true foundation of sustainable agriculture.

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ORNAMENTAL PALMS: THE LIVING ELEGANCE OF LANDSCAPES

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Introduction

Ornamental palm trees are among the best choices to add elegance and beauty to various spaces, whether they are home gardens, public squares, or even indoor spaces. Ornamental palms can transform a place into an attractive and visually pleasing environment with their unique designs that reflect the elegance of nature. Ornamental palms are a diverse group of tropical and subtropical plants belonging to the family **Arecaceae (Palmae),** valued primarily for their attractive foliage, unique growth habit, and aesthetic appeal. Palms are highly versatile, some species are **towering and majestic**, ideal for avenues and large gardens, while others are **compact and slow-growing**, making them suitable for pots, patios, or indoor decoration. Beyond their ornamental value, palms also provide **shade, environmental benefits, and cultural significance** in many regions of the world.

Different Types of Ornamental Palm Trees:

1.Date Palm
2.Areca Palm
3.Mexican Fan Palm
4.European Fan Palm
5.Windmill Palm
6.Pygmy Date Palm
7.Pindo Palm
19.Bismarck Palm
20.Foxtail Pall
21.Coconut Palm
22.Kentia Palm
23.Lady Palm
24.Saw Palm
25.Sabal Palm

8.Triangle Palm
9.Mediterranean Dwarf Palm
10.Mazari Palm
11.Dwarf Majesty Palm
12.Chirstmas Palm
13.Bottle Palm
14.Sago Palm
15.Queen Palm
16.King Palm
17.Canary Island Date Palm
18.Chinese Fan Palm
26.Spindle Palm
27.Traveler's Palm
28.Fishtail Palm
29.Royal Palm
30.Alexander Palm
31.Bangalow Palm
32.Lipstick Palm
33.Yellow Butterfly Palm
34.Red Feather Palm
35.Blue Hesper Palm

ORNAMENTAL PALMS:

1.Areca Palm: *Chrysalidocarpus lutescens*

- The areca palm is believed to bring health, wealth and prosperity to a home.
- As per Vastu and Feng Shui, areca palm can be placed in the east, southeast, south or north to bring positivity to the house.
- The Areca palm reduces harmful substances and increases the amount of oxygen in the room.
- It is often considered to be the best air purifying plant.
- They are best known as the Yellow Butterfly and one of the best plants to add to the decor of your house.
- In Feng Shui principles, Areca Palm brings wealth, prosperity, and peace to your house.

2. Royal Palm: ***Roystonea regia***

- It is a majestic, tall palm tree known for its smooth, gray-white trunk and large, feather-like fronds.
- It's a fast-growing tree, reaching heights of 50 to 80 feet, and is a popular choice for adding height and drama to landscapes.
- Its distinctive appearance, with a slightly swollen base and a crown of arching fronds, makes it a striking focal point.
- Royal Palms are often used in landscaping for their ability to create a tropical ambiance, and they are commonly seen lining driveways and streets in coastal areas
- The Royal Palm Tree can live for over 100 years, making it a long-lasting addition to your garden

3. Bottle Palm: ***Hyophorbe lagenicaulis***

- It has a single, clean, white, waxy trunk ringed by the scars from the fallen fronds.

- The crown-shaft is covered in dense reddish-brown velvet like or fur-like fuzzy material, thus it is also named Teddy Bear Palm.
- Bottle palms have only four to six leaves open at any time.
- The leaves of young palms have a red or orange tint, but a deep green is assumed at maturity.
- The flowers of the palm arise from under the crownshaft, the trunk of the Bottle palm swells from near the base and tapers further up.
- Its inflorescence branches in 4 orders, and its 2.5 cm fruits can be orange or black.

4. Foxtail Palm: ***Wodyetia bifurcate***

- The Foxtail Palm is celebrated for its bushy crown of feathery foliage, resembling a fox's tail, and is a favorite choice for landscaping.
- This slow-growing beauty takes 10-20 years to reach maturity, allowing you to enjoy its exquisite charm for years to come.
- With a spread of 10-15 feet, this palm adds a touch of elegance to any garden.
- Foxtail palms are relatively hardy and can tolerate a range of soil conditions, making them suitable for various environments.
- The combination of the foxtail-like fronds, smooth trunk, and vibrant green crown shaft creates a visually striking and elegant appearance.

5.Fishtail Palm: ***Caryota urens***

- The Fishtail Palm is a stunning and versatile plant that brings a touch of the tropics to any landscape.

- Its unique, fishtail-shaped leaves, manageable growth requirements and diverse uses make it a cherished addition to gardens, parks and indoor spaces

- They are ideal as a standalone specimen, in clusters, or as a natural screen or hedge.
- Young Fishtail Palms can be grown in large pots for indoor or patio decoration, adding a dramatic tropical flair.
- Some fishtail palm species are known for their air-purifying qualities, helping to remove toxins and improve air quality in indoor spaces.

6. **Fan Palm:** ***Livistona chinensis***

- Fan palm differs from other palms with the more traditional feathery fronds with star-shaped leaves.
- Although it grows slowly, the full height of this type of palm can be up to 15 feet.
- Fan palms can thrive both indoors and outdoors, making them suitable for various locations like living rooms, balconies, patios, and gardens.
- They are also known for their air-purifying qualities, helping to filter toxins and improve indoor air quality.

- Fan palms are relatively easy to care for, requiring minimal watering and maintenance, making them ideal for busy individuals.

Conclusion

Ornamental palms are among the most graceful and versatile plants used in landscaping and interior decoration. With their unique forms, evergreen foliage, and ability to adapt to a wide range of environments, they bring both beauty and ecological benefits to the surroundings. From the majestic Royal Palm and Foxtail Palm that add grandeur to avenues and gardens, to compact varieties like Areca Palm and Fan Palm that thrive indoors, palms suit every landscape requirement. Beyond their aesthetic value, many ornamental palms also contribute to cleaner air, provide shade, and hold cultural significance in different regions of the world. Their elegance, longevity, and adaptability make them an integral part of modern urban greening and sustainable landscaping practices.

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PROPAGATION OF GUAVA THROUGH AIR LAYERING-A SUSTAINABLE TECHNIOUE

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Introduction

Guava (Psidium guajava L.) is a tropical fruit known for its unique flavor, nutritional value, and medicinal properties. It is a significant fruit in terms of its economic value in the global market and its role in the diet of many cultures .Guava is propagated through seeds or vegetative methods like grafting, cutting, and budding. While these methods have been moderately successful, they are not without limitations. However, the propagation of guava, particularly in commercial settings, often encounters challenges such as low seed viability, prolonged juvenile phase, and genetic variability when propagated sexually. In light of these challenges, there is a growing interest in exploring more efficient and reliable vegetative propagation techniques. Air layering, known for its potential in various other fruit species, presents a promising alternative. This method involves inducing root formation on a stem while it is still attached to the parent plant, potentially offering higher success rates and uniformity among the propagated plants.

AIR LAYERING:

Air layering in guava *is a* vegetative propagation technique used to produce new guava plants from a mature parent tree, without the use of seeds. It involves inducing root development on a selected branch while it is still attached to the parent plant. Once roots form, the branch is cut and planted as a new, independent guava tree. Air layering technique is successful in propagating plants because, the layered branch is not detached from the mother plant therefore, it receives continuous supply of water and mineral nutrients through the xylem and remains alive

(Hartmann et al., 2010) and intact shoots (with leaves) possibly synthesize some unknown auxiliary substances which help in induction of adventitious roots (Singh et al., 2004) In guava, two types of layering is commonly adopted viz., **Air layering/ Marcottage and Mound/Stool layering**. Among the vegetative methods of guava propagation, air layering with the help of growth substances (IBA, NAA) is a successful method of propagation (Tyagi and Patel, 2004). Air layering technique is successful in propagating plants because, the layered branch is not detached from the mother plant therefore, it receives continuous supply of water and mineral nutrients through the xylem and remains alive (Hartmann et al., 2010) and intact shoots (with leaves) possibly synthesize some unknown auxiliary substances which help in induction of adventitious roots (Singh et al., 2004). This is a **quick, efficient & simple, way to clone guava plants** and could be the most inexpensive technique. In layering, success depends on the early beginning of the root and on the formation of sufficient fibrous roots... Air layering have been found very successful in guava, litchi and many other fruit species.

ADVANTAGES

- Produces true-to-type plants identical to the mother plant.
- Simple and inexpensive technique requiring minimal skill and tools.
- Rooted plants bear fruits earlier (3–4 years) compared to seedling plants (5–7 years).
- High success rate when practiced during favorable season.
- Maintains uniformity in orchard establishment

PROPAGATION PROTOCOL :

The most ideal time for air layering in guava is between **April and June** in the warm and humid climate.

↓

The average temperature varies between **29.3 and 30.5°C and relative humidity between 69.0 and 80.0 percent.**

↓

A shoot from previous year's growth of 1cm in diameter is selected for air-layering.

↓

A ring of bark about 3cm long is removed.

↓

This area is covered with wet sphagnum moss and tied with polyethylene film.

↓

The rooting takes place in **about 30-40 days**.

PROCEDURE

1.Selection of Branch: Choose a healthy, disease-free branch of 1–2 years old and pencil-thickness (0.5–1.5 cm).

2.Girdling: Remove a ring of bark about 2–3 cm wide at a suitable point on the branch.

3.Hormone Treatment: Apply rooting hormones such as Indole-3-butyric acid (IBA) or Naphthalene acetic acid (NAA) in paste/powder form to promote root initiation.

4.Wrapping: Cover the girdled portion with moist sphagnum moss, sawdust, or soil mixture.

5.Polythene Covering: Wrap tightly with transparent polythene sheet to conserve moisture. Both ends are tied securely to prevent drying.

6..Root Formation: Roots usually appear within 6–8 weeks during the monsoon or rainy season when humidity is high**.**

7.Separation and Planting: Once sufficient roots are visible, the layered branch is cut just below the rooted portion, transplanted into polythene bags with soil mixture, and hardened before field planting.

LIMITATIONS:

- Not suitable for large-scale commercial propagation, as it is time-consuming.
- Rooted layers often develop a weak root system, making them less tolerant to drought or wind compared to grafted plants.
- Labor-intensive if many plants are required.

Conclusion

Air layering is an effective method for propagating guava trees, offering higher success rate compared to traditional methods like seed propagation. By using growth regulators like IBA and selecting the right time of year, particularly during the monsoon season, growers can significantly enhance root development and overall success of the air layering process. This method allows for the cloning of desirable traits from the parent plant, resulting in a more uniform and productive orchard.

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SHIITAKE MUSHROOM: IMPORTANCE AND HEALTH BENEFITS

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Abstract

Shiitake mushroom (Lentinula edodes), a wood-dwelling fungus native to East Asia, is both a culinary delicacy and a valuable medicinal resource. Rich in proteins, dietary fibre, vitamins, minerals, and bioactive compounds such as lentinan, eritadenine, and ergothioneine, shiitake mushrooms exhibit diverse pharmacological properties, including antioxidant, antimicrobial, anti-inflammatory, anticarcinogenic, and lipid-lowering effects. Traditionally cultivated on hardwood logs for over a thousand years, they are now grown commercially using sustainable methods like sawdust-based substrates, minimizing environmental impact. Shiitake mushrooms support immune function, improve cardiovascular health by reducing cholesterol, and may aid in weight management and cancer prevention. Nutritionally, they are notable for high copper content, B-vitamins, and essential amino acids. Beyond health benefits, shiitake mushrooms contribute to environmental sustainability through bioremediation potential and use in producing bioactive compounds and bioenergy. With their unique flavour, versatile applications, and significant medicinal value supported by both traditional use and modern research, shiitake mushrooms hold an important role in promoting human health and ecological balance.

Introduction

The term "mushroom" refers to the “fruiting body of a fungal organism that usually rises above the soil and contains spores.” It is this fleshy fruiting body that is commonly consumed and reproduces by spreading spores, similar to how other plants release seeds.

Mushrooms are excellent sources of proteins, minerals, and vitamins, which play an important role in nutrition.Medicinal mushrooms exhibit a variety of pharmacological effects, including antimicrobial, anti-inflammatory, immunomodulatory, antidiabetic, cytotoxic, antioxidant, hepatoprotective, anticancer, antiallergic, antihyperlipidemic, and prebiotic activities, among others.

Shiitake mushrooms have a historical background of medicinal usage. This particular mushroom is utilized for its anticarcinogenic, anti-inflammatory, antioxidant, antifungal, antibacterial, antiviral, and antithrombotic properties in relation to cardiovascular conditions.

Shiitake mushroom:

The shiitake mushroom (Lentinula edodes) is categorized under Class Basidiomycetes, Order Agaricales, and Family Marasmiaceae. This edible and medicinal fungus, which thrives on wood, is indigenous to East Asia. Shiitake mushrooms are among the most widely cultivated fungi worldwide. The name shiitake originates from "shii," referring to the Castanopsis cuspidata tree, a hardwood on which these mushrooms commonly grow, combined with "take," the Japanese word for mushroom.

Lentinula edodes is originally found in the mountainous areas of Japan, Korea, and China, where it flourishes on decaying logs. This species has a rich history of culinary and medicinal use across East Asia, with wild shiitake being collected for food and traditional remedies. The first evidence of shiitake cultivation in China dates back approximately 1,000 to 1,200 years, where it was known as dongo or shanku. These mushrooms have a deep, earthy flavor and a taste often described as meaty.

Shiitake mushrooms decompose organic matter from the deadwood of broad-leaved trees, particularly oaks and other species within the order Fagales. The fruiting bodies of these fungi typically have a light to reddish-brown color, featuring a dome-shaped cap (pileus) supported by a fibrous stalk (stipe). The cap ranges from 8 to 15 cm (3 to 6 inches) in diameter and displays white gills on the underside. Characteristically, these mushrooms produce white spores.

In commercial cultivation, these fungi are often grown on logs, sawdust blocks, or sawdust pellets.

Medicinal Properties of Shiitake Mushroom:

The shiitake mushroom is used as anticarcinogenic, anti-inflammatory, antioxidant, antifungal, antibacterial, antiviral as well as antithrombotic in cardiovascular disorders.

Shiitake mushrooms are recognized for their bioactive substances, which include:

1. Lentinan – a β-(1-3)-glucan polysaccharide known for its immune-enhancing and antimicrobial features; it is effective against Mycobacterium tuberculosis and Listeria monocytogenes.
2. Eritadenine – helps lower cholesterol production.
3. Ergothioneine – an antioxidant amino acid that safeguards against oxidative damage.

These compounds provide lipid-lowering, antimicrobial, and antioxidant benefits. Studies indicate that shiitake extracts can diminish harmful oral bacteria associated with cavities and gum disease. Shiitake mushroom has high level of antioxidants protect against oxidative stress, reducing the risk of chronic diseases like heart disease.

Importance

Shiitake mushrooms are highly sought after for their culinary and medicinal applications, making them popular in the market.

They are rich in essential vitamins, minerals, and proteins, appealing to health-conscious consumers.

These mushrooms can be cultivated with minimal environmental impact. Sawdust serves as a waste material that is used in mushroom cultivation, highlighting its eco-friendly nature.

Mushrooms show significant potential for cleaning up polluted soil and water. They can also be employed to create nanoparticles, bioactive substances, bioenergy, and for nano remediation.

Health Benefits of Shiitake mushroom:

Shiitake mushrooms (Lentinula edodes) are among the richest natural sources of copper, a mineral essential for maintaining healthy blood vessels, bones, and immune function. These mushrooms offer numerous health advantages that can assist with weight loss.

Enhancement of the immune system

Shiitake mushrooms are beneficial for boosting immunity and promoting liver health while supporting the cardiovascular system. Lentinan, a polysaccharide found in shiitake mushrooms, protects against cellular damage, enhances immune function, and stimulates white blood cell production to combat microbes, along with exhibiting anti-inflammatory benefits.

Research indicates that shiitake mushrooms can elevate levels of IgA, a crucial immune cell (immunoglobulin) that serves as a primary line of defense in immunity.

Improvement of heart health

Shiitake mushrooms feature three components that help reduce blood cholesterol levels.

a) Eritadenine inhibits an enzyme responsible for cholesterol production.

b) Sterol compounds block the intestines from absorbing cholesterol.

c) Beta glucans, a type of fiber, can contribute to lowering cholesterol.

Others

• The polysaccharides present in shiitake mushrooms may possess anticancer properties. Lentinan may aid in combating cancer.

• Shiitake mushrooms may assist with weight management due to their fiber content and the metabolic effects of eritadenine and beta-glucans.

• High levels of vitamin D in shiitake mushrooms may promote improved bone density.

Nutritive Values of Shiitake mushroom:

Shiitake mushrooms are abundant in a high content of dietary fiber, B vitamins (particularly pantothenic acid), and essential minerals such as copper, selenium, manganese, and iron. When dried, shiitake mushrooms are abundant in carbohydrates and protein. Their composition consists of 58-60% carbohydrates, 20-23% protein (with an 80-87% digestibility rate), 9-10% fiber, 3-4% fats, and 4-5% ash.

According to the United States Department of Agriculture (USDA), 100g of raw shiitake mushrooms contain:

S.NO.	NUTRIENT	AMOUNT
1.	Fat	0.5 g
2.	Protein	2.63 g
3.	Carbohydrate	6.57 g
4.	Cholesterol	0 g
5.	Energy	34.2 calories
6.	Vitamin D	0.4 mcg
7.	Vitamin B-2 (Riboflavin)	0.22 mg
8.	Vitamin B-5 (Pantothenic Acid)	1.5 mg
9.	Vitamin B-3 (Niacin)	3.95 mg
10.	Vitamin B-6	0.30 mg
11.	Calcium	2.63 mg
12.	Iron	0.40 mg
13.	Potassium	303.95 mg
14.	Copper	0.14 mg

***g for gram, mg for milligram, mcg for microgram.**

Conclusion

Shiitake mushrooms (Lentinula edodes) emerge as a distinctive blend of culinary pleasure and medicinal benefits. Their impressive nutrient profile, which includes crucial vitamins, minerals, proteins, and bioactive compounds like lentinan, eritadenine, and ergothioneine, offers numerous health advantages—from enhancing the immune system and promoting heart health to demonstrating anticancer and antimicrobial effects. In addition to individual health benefits, shiitake mushrooms play a role in environmental sustainability through their low-impact farming techniques and possible uses in bioremediation. With a longstanding presence in traditional medicine and an expanding array of modern scientific validation, shiitake mushrooms occupy a significant position in both nutrition and natural health, presenting valuable prospects for human wellness and ecological balance.

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ASSESSMENT OF SEAWEED DIVERSITY AND ECOLOGICAL IMPORTANCE IN KADIYAPATTINAM AND MUTTOM, KANNIYAKUMARI DISTRICT

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Abstract

The rocky intertidal environments of Kadiyapattinam and Muttom, on India's southwest coast, are impacted by the Arabian Sea and sustain a variety of seaweed populations. Fifteen species six Chlorophyta, five Ochrophyta, and four Rhodophyta were identified in this study using both contemporary methods and traditional low-tide handpicking. Morphological and habitat traits were used for identification. Seaweeds contribute to marine biodiversity and have economic worth in food, fertilizers, cosmetics, pharmaceuticals, and possibly biofuels. They are also essential primary producers, nutrient cyclers, and habitat providers. These resources are threatened by overfishing, pollution, habitat loss, and climate change, though. In order to guarantee long-term ecological and financial benefits, sustainable practices such as controlled harvesting, aquaculture, marine protected areas, and community involvement are crucial.

Introduction

The Arabian Sea borders Kadiyapattinam and Muttom, which is located at the southernmost tip of India. This creates a variety of maritime ecosystems that are abundant in seaweeds, or macro algae. From tiny filamentous forms to massive kelps, these are essential primary producers, habitat providers, and participants in carbon sequestration and nutrient cycling. Some species produce agar, carrageenan, and alginate for the food, pharmaceutical, and cosmetic industries, while others, including *Ulva lactuca* and *Sargassum polycystum*, are valued economically as food. Biofuels from seaweed are also being investigated. Seaweeds have historically been responsibly gathered by coastal people for use as fertilizer, food, and medicine, combining cultural heritage with practical necessities. These resources are threatened by overuse,

pollution, coastal development, and climate change, though. Sustainable harvesting practices and marine protected areas are crucial conservation measures. This paper reviews the collection and identification of Kanniyakumari's seaweed species, their ecological and economic significance, threats, and the potential of seaweed farming, aiming to guide sustainable management and conservation.

Seaweed Diversity in India:

India, one of the 12 mega-biodiversity nations, has an 11098.81 km long coastline. The Central Salt and Marine Chemicals Research Institute (CSMCRI) conducted comprehensive surveys in the 1980s and 1990s, estimating significant seaweed standing stocks from the coasts of Tamil Nadu, Andhra Pradesh, and Lakshadweep, with Tamil Nadu contributing the highest amount.

Seaweed Diversity in Tamil Nadu

The Tamil Nadu coastline spans (1068.69km) and features a mix of intertidal and subtidal environments influenced by the confluence of the Bay of Bengal, Arabian Sea, and the Indian Ocean. Northern Tamil Nadu has sandy beaches and rocky regions with algae like *Ulva*, *Chaetomorpha*, and *Grateloupia*, while the central coast (Palk Bay) is home to *Gracilaria* species, important for commercial harvesting. The Gulf of Mannar in the south is known for its diverse seaweed species, with 282 species recorded across 42 coastal stations and 14 Gulf of Mannar islands.

Seaweed Diversity in Kanniyakumari

The southern Indian state of Tamil Nadu contains the seaside town of Kanyakumari. In Tamil Nadu, it is one of the most visited tourist destinations. The Kanyakumari coast is rocky. The exposed rocky parts are covered in macro algae and are subject to tides. In the Kanniyakumari district, the villages of Kurumpanai, Manavalakurichi, Muttom, Kovalam, Kadiyapattanam, and Leepuram have abundant seaweed resources.

Material and Methods:

The current investigation was conducted in the Arabian Sea off the southwest coast of India at Kadiyapattanam. Kadiyapattinam boasts a stunning, well-kept beach with rocky shorelines that exhibit an incredible amount of species. The beach appears immaculate because of the massive boulders that stand on either side of it. I have collected 15 species, 6 species from

Chlorophyta (Green seaweed), 5 species from Ochrophyta (Brown seaweed), and 4 species from Rhodophyta (Red seaweed).

Seaweed Collection Methods:

In Kanniyakumari, gathering seaweed has long been a custom. It is primarily carried out by hand when the intertidal zones are exposed at low tide. To cut seaweed without harming the ecosystem, collectors use their hands or instruments like sickles and knives. Snorkelling and diving are used in deeper subtidal locations. Seaweed is cleaned of sand and debris after collection, and it is then either artificially or naturally dried before being stored. A sustainable substitute that guarantees a consistent supply and lessens the strain on natural populations is seaweed farming, which is done in shallow waters with ropes or nets. Modern methods involve boats for remote collection, along with GPS and remote sensing to locate seaweed-rich zones efficiently and sustainably.

Identification of Seaweeds:

Seaweed identification in Kanniyakumari relies on macroscopic features (colour, texture, shape, size of thallus) and microscopic structures (reproductive organs like cyst carps in red algae and sporangia in brown algae). Habitat type—rocky shores, sandy beaches, or coral reefs—also aids recognition.

Seaweeds are grouped into:

Green algae (Chlorophyta): Bright green (chlorophyll-rich); e.g., Ulva spp, Caulerpa spp, Codium spp, Enteromorpha spp.

Brown algae (Ochrophyta): Brown/olive (fucoxanthin pigment); e.g., Sargassum spp, Padina spp, Turbinaria spp, Laminaria spp, Undaria spp.

Red algae (Rhodophyta): Red/purple (phycoerythrin pigment); e.g., Gracilaria spp., Porphyra spp., Chondrus spp, Euchamea spp, Gelidilla spp.

Class	Order	Family	Species
Ulvophycea	Ulvales	Ulvaceae	*Ulva rigida*
			Ulva lactuca
	Bryopsidales	Caulerpaceae	*Caulerpa racemosa*
			Caulerpa chemnitzia
	Cladophorales	Valoniaceae	*Valoniopsis pachynema*

		Cladophoraceae	*Chaetomorpha antennina*
Phaeophycea	Fucales	Sargassaceae	*Sargassum vulgare*
			Sargassum swartzii
			Turbinaria conoides
	Dictyotales	Dictyotaceae	*Padina boryana*
			Padina boergesenii
Florideophyceae	Gracilariales	Gracilariaceae	*Gracilaria pulvinata*
			Gracilaria tsudae
			Gracilaria multipartita
	Ahnfeltiales	Ahnfeltiaceae	*Ahnfeltia plicata*

Ulva rigida

Ulva lactuca

Caulerpa racemose

Caulerpa chemnitzia

Valoniopsis pachynema

Chaetomorpha antennina

Sargassum vulgare

Sargassum swartzii

Turbinaria conoides

Padina boryana

Padina boergesenii

Gracilaria pulvinata

Gracilaria tsudae

Gracilaria multipartita

Ahnfeltia plicata

Ecological significance:

Seaweeds are essential to marine ecosystems because they are primary producers, turning nutrients and sunlight into organic matter that serves as the foundation for marine food webs. For many marine animals, such as fish, molluscs, and crustaceans, they offer vital habitats. They also serve as cradles for fish, sea turtles, and other organisms in their juvenile phases. Seaweeds absorb excess nitrogen and phosphorus through nutrient cycling, preventing hazardous algal blooms and eutrophication. Floating mats created by some species, like *Sargassum spp*., provide pelagic animals with cover and serve as nurseries for marine life. In general, seaweed ecosystems support the stability and health of ocean environments while also greatly enhancing marine biodiversity.

Economic Importance of Seaweeds:

- **Food Industry:** Edible algae like Ulva (sea lettuce) and Porphyra (nori) are valuable food sources.
- **Polysaccharide Production:** Source of agar, carrageenan, and alginate, used in pharmaceuticals, cosmetics, and foods.

- **Seaweed Farming:** Supports sustainable livelihoods and aids marine conservation.
- **Biofuel Production:** Potential raw material for renewable biofuels.
- **Natural Fertilizers**: Used as eco-friendly fertilizers in agriculture.
- Economic Opportunities: Rising demand for seaweed-based products boosts regional economies.

Conservation and Sustainable Management:

Seaweed conservation and sustainable management include controlling harvesting practices to minimize overfishing, encouraging appropriate waste management to prevent contamination, and safeguarding vital habitats like mangroves and coral reefs. Involving local communities in ethical farming and collection methods, creating marine protected areas (MPAs) to preserve ecosystems and biodiversity, and creating regulated seaweed aquaculture systems to reduce environmental effects while guaranteeing a steady supply are all part of it.

Conclusion

Seaweeds Kadiyapattinam and Muttom in Kanniyakumari District are vital for both ecology and economy, supporting marine food webs, providing habitats, and offering raw materials for various industries. With growing demand, sustainable farming and conservation are essential to protect biodiversity, prevent overharvesting, and ensure long-term benefits for future generations.

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COCONUT MOTHER PALM SELECTION AND NURSERY MANAGEMENT

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Introduction

Coconut (*Cocos nucifera* L.) known as "Tree of Life," is one of the most valuable plantation crops grown across tropical and subtropical regions of the world. From its roots to the crown, every part of the coconut palm contributes to human livelihood in the form of food, drink, oil, fiber, timber, fuel, and countless other by-products. In countries like India, Sri Lanka, the Philippines, and Indonesia, coconut farming supports millions of small and marginal farmers, serving as both an economic lifeline and a cultural symbol. The productivity and profitability of coconut plantations, however, depend largely on the quality of planting material used. Unlike annual crops, coconut is a perennial tree that remains productive for 60–80 years. This means that a poor choice of seedlings can affect several generations of farmers, leading to reduced yields, vulnerability to diseases, and economic losses. Hence, the importance of establishing well-managed coconut nurseries cannot be overstated. A nursery acts as a "cradle of plantations," where healthy seedlings are raised under controlled conditions before being transplanted to the main field.

1. Selection of Mother Palms

The starting point of coconut nursery production lies in identifying superior mother palms. Only high-yielding, disease-free palms are chosen for seed production. The following criteria are considered:

- **Age**: Ideal palms are 20–40 years old, a stage when yield is stable.

- **Yield**: Palms producing 100 or more nuts annually are preferred.
- **Fruit Traits**: Medium-sized nuts with round or oval shape, sweet water, and well-filled kernel are selected.
- **Stem Characteristics**: Straight trunk with short internodes indicates good genetic potential.
- **Disease-Free plants**: Mother palms must be free from diseases like root wilt or pests like rhinoceros beetle.

SELECTION OF MOTHER PALM

2. Seed Nut Collection and Storage

Seed nuts are harvested during the main fruiting season (commonly between January–May in India). Mature nuts selected should be 11–12 months old. These nuts are then stored in a cool, shaded, and well-ventilated place for **30–45 days**, which helps in uniform sprouting after sowing. Storing in vertical stacks with husk ends alternated ensures aeration and prevents overheating.

MATURED NUT

3. Nursery Site and Preparation

The location of the nursery plays a decisive role in seedling development. A well-chosen nursery site should have:

- **Soil**: Light-textured, well-drained soil to prevent waterlogging.
- **Water Source**: Reliable irrigation facilities.

- **Protection**: Shelter from strong winds, scorching sunlight, and grazing animals.
- **Accessibility**: Easy approach for transport of nuts and seedlings.

NURSERY BED PREPARATION

4. Methods of Sowing

Seed nuts can be sown in different orientations:

- **Vertical Sowing**: With stalk end upward. Germination is slower but requires less space.
- **Horizontal Sowing**: Nuts are laid flat with the stalk end slightly raised. This method is most popular as it results in rapid, uniform sprouting and healthy seedlings.
- **Slanting Method**: A variation where the stalk end is tilted upward.

The nuts are sown in lines with a spacing of **30–60 cm**, depending on whether it is a **seed bed nursery** or **polybag nursery**.

5. Types of Coconut Nurseries

(a) Bed Nursery: This is the traditional method where nuts are sown in raised beds, either in rows or blocks. The soil is loosened, manured, and kept moist. This method is cost-effective but requires more land and careful weeding.

(b) Polybag Nursery

An advanced and increasingly preferred system. Nuts are first allowed to sprout in beds and then transferred to **black polybags (60 × 40 cm)** filled with a soil-sand-compost mix.

Advantages of polybags:

- Root system develops better and remains undisturbed.

- Seedlings can be easily transported to distant places.
- Transplant shock is reduced.
- Uniform growth is achieved.

6. Nursery Management and Care

Managing seedlings for 8–12 months requires close attention to water, nutrition, and protection.

- **Irrigation**: Seedlings need consistent moisture. Over-watering should be avoided to prevent fungal diseases.
- **Weeding**: Regular weeding ensures no competition for nutrients. Mulching may be used to retain moisture.
- **Fertilization**: Application of organic manure and biofertilizers like Azospirillum and phosphate-solubilizing bacteria improves growth.
- **Pest and Disease Control**:
    - *Damping-off* and *root rot* are common fungal problems, controlled by proper drainage and fungicidal seed treatments.

  Insect pests such as rhinoceros beetle and red palm weevil are managed by sanitation, use of pheromone traps, and biological agents like Metarhizium fungus.

7. Seedling Selection for Planting

Not all seedlings are suitable for field planting. Farmers must carefully choose the best-performing plants:

- Seedlings should be **8–12 months old**.
- Must have **6–8 healthy leaves**.
- Collar girth should be **10–12 cm**.
- Should display robust root growth and upright stem.
- Weak, diseased, or deformed seedlings are rejected.

This rigorous selection ensures that only vigorous seedlings with high survival chances are planted in the field.

8. Advanced and Modern Approaches

While traditional nursery methods are effective, new scientific approaches are revolutionizing coconut nursery production:

- **Tissue Culture**: Produces large numbers of uniform, disease-free seedlings from elite palms.
- **Embryo Culture**: Used for conserving rare varieties and transporting germplasm.
- **Organic Inputs**: Increasing use of biofertilizers, neem cake, and compost to produce eco-friendly seedlings.
- **Smart Irrigation**: Drip and micro-sprinkler systems maintain uniform soil moisture with minimal water use.
- **Digital Monitoring**: Farmers are adopting mobile apps and sensors to track seedling health and growth.

Conclusion

Coconut nursery production forms the foundation of a productive and sustainable coconut industry. The careful selection of mother palms and seed nuts, proper nursery establishment, and scientific management of seedlings are not just preliminary tasks but essential investments for decades of yield and livelihood security. Since coconut is a long-lived crop, the decision made at the nursery stage has long-term implications on the success or failure of entire plantations. Strong, disease-free, and uniform seedlings result in higher survival rates, better resistance to environmental stresses, and ultimately superior nut yields.In today's era, coconut nursery production is evolving from small-scale traditional practices into more organized, technology-driven systems. Polybag nurseries have made seedling handling easier, tissue culture promises large-scale multiplication of elite varieties, and sustainable methods ensure minimal ecological impact. Farmer-participatory approaches in mother palm selection and the establishment of community seed gardens are also steps toward improving planting material availability.

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GRAFTING IN MANGO

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Introduction

Mango (*Mangifera indica L.*) is one of the oldest and most celebrated tropical fruit crops in the world, popularly known as the "King of Fruits." It is cultivated widely across tropical and subtropical regions for its delicious fruits, nutritional value, and high commercial demand. India, being the largest producer, also serves as a pioneer in mango research and orchard management. Mango is a highly heterozygous and cross-pollinated plant, meaning that propagation through seeds does not produce true-to-type plants. Seedlings grown from mango stones often vary greatly in fruit quality, tree size, and productivity. To overcome these challenges, vegetative propagation techniques, particularly grafting, are employed. Grafting provides an efficient means to maintain superior genetic traits, reduce juvenile periods, and establish productive and uniform orchards.

GRAFTING

Grafting is a horticultural technique in which a scion (a shoot or bud from the desired variety) is physically joined to a rootstock (a young seedling or established root system). Once the union heals, both parts grow together as a single plant.

In mango, grafting is the most widely used method of propagation because it ensures:

- Genetic fidelity of elite cultivars.
- Early bearing (fruiting in 3–4 years instead of 7–8 years in seedlings).
- Control of tree size (dwarfing or vigour regulation depending on rootstock).

- Resistance to local soil conditions, pests, and diseases.

OBJECTIVES OF GRAFTING IN MANGO

1. To produce true-to-type mango plants with desired varietal characters.
2. To shorten the juvenile period and induce early fruiting.
3. To ensure uniformity in orchard establishment.
4. To improve adaptability to different soils and climates.
5. To multiply superior mother trees on a large scale.
6. To facilitate high-density planting and better orchard management.

SELECTION OF ROOTSTOCK

The success of grafting largely depends on the quality of rootstock.

- **Varieties used**: Polyembryonic mango varieties such as Olour, Bappakai, Vellaikolamban, or local seedlings adapted to the area. Varieties like *Peach* and *Sabre* are considered excellent rootstocks.
- **Age and size**: Seedlings should be about **6 months old**, at least **25 cm tall**, and with stem thickness similar to a pencil.
- **Health**: Rootstock must be free from pests, diseases, and deformities. Vigorous, straight seedlings ensure strong graft unions.
- **Environmental adaptability**: Rootstock should be suited to the local soil and climatic conditions.

SELECTION AND COLLECTION OF SCIONS

The scion is the most crucial component since it forms the upper part of the grafted plant.

- **Source**: Scions must be obtained from a **healthy, high-yielding mother tree** of the desired variety (e.g., Alphonso, Dashehari, Kesar, Langra, Banganapalli).
- **Size**: Selected scions should be about **10 cm long**, pencil-thick, and carry an active, healthy terminal bud.
- **Preparation**: Leaves are removed carefully, leaving only petiole stubs to reduce water loss.
- **Storage**: Freshly cut scions should be wrapped in moist newspaper, placed in a plastic bag, and transported quickly. If storage is necessary, scions may be kept in a zip-lock bag in a cool, dark place, but not longer than **7 days**.

Best time to collect scions: During **warm and humid weather**, just before a new flush of growth.

Avoid scions from:

- Diseased or insect-infested branches.
- Over-mature or woody shoots.
- Branches that are flowering or fruiting.
- Crowded or shaded lower branches.

STEP-BY-STEP GRAFTING PROCEDURE

1. Sterilize tools and prepare materials.
2. Select healthy rootstock and scion of matching thickness.
3. Cut rootstock (decapitation or side slit depending on method).
4. Shape scion into a wedge or veneer cut.
5. Insert scion into rootstock ensuring cambial contact.
6. Bind tightly with polythene strip.
7. Cover graft to maintain humidity (optional polythene sleeve).
8. Keep grafted plants in partial shade, irrigate carefully.
9. After 14–21 days, successful grafts show sprouting of new leaves.
10. Remove binding tape after union has healed (30–40 days).

TYPES OF GRAFTING IN MANGO

STONE GRAFTING (EPICOTYL GRAFTING):

This is one of the most popular and economical methods, especially in southern India. It is performed on very young germinating seedlings that are about 7 to 15 days old. The epicotyl portion of the seedling is decapitated 6 to 8 cm above the ground, and a vertical slit is made. A wedge-shaped scion prepared from a desirable variety is then inserted into the slit, and the joint is tied with a polythene strip. The entire graft is covered with a transparent polythene bag to maintain humidity, which promotes quick union. This method is usually practiced during the monsoon months of June to August when fresh seeds are available. Stone grafting is cheap, simple, and suitable for mass multiplication in nurseries, with a success rate of 60 to 80 percent.

SOFTWOOD GRAFTING:

In this method, slightly older rootstocks, about six to twelve months old, are used. The rootstock is cut at a height of 10 to 15 cm from the ground, and a vertical slit of about 3 to 4 cm

is made. The scion, prepared with a wedge cut at the base, is inserted into this slit and tied firmly with a polythene strip. A transparent polythene tube is placed over the graft to create a humid microclimate. This technique can be practiced twice a year, in July–August and February–March. Softwood grafting has a high success rate, usually ranging from 70 to 90 percent, and produces vigorous plants with rapid growth.

VENEER GRAFTING:

Veneer grafting is another widely used method, especially in northern India. Here, the rootstock is usually one to two years old. A downward cut of 2.5 to 3 cm length is made on the stem of the rootstock, and a small notch is created at the base of the cut. The scion is prepared with a similar cut and fitted precisely into the notch. The joint is then tied tightly with a polythene strip to prevent moisture loss. Veneer grafting is generally performed during the monsoon and spring seasons, that is, in July–August and February–March. The success rate ranges from 60 to 75 percent, and the method produces strong graft unions, although it is more labour-intensive compared to stone grafting.

INARCHING (APPROACH GRAFTING):

This is one of the oldest methods of mango propagation and is still practiced in some areas. In this technique, potted rootstock seedlings are brought close to the branches of a selected scion tree. Matching cuts are made on both stock and scion, and the two are tied together. After the union is established, which takes a few weeks, the scion is severed from the mother plant, and the rootstock is cut above the union. Although inarching produces very strong plants, it is time-consuming, labour-intensive, and not suitable for large-scale commercial multiplication. The success rate is usually between 50 and 60 percent.

SIDE GRAFTING:

This method is quite similar to veneer grafting, except that the cut is made on the side of the rootstock instead of the front face. It is practiced in some regions with moderate success and is useful when the grafting season is extended or when rootstocks are not in ideal condition.

Besides these main methods, other grafting techniques such as cleft grafting, wedge grafting, and tongue grafting are also tried experimentally, though they are not as popular for routine mango propagation.

AFTERCARE OF GRAFTED PLANTS

- Keep plants under partial shade until hardened.

- Water regularly but avoid overwatering.
- Remove unwanted shoots from rootstock below graft union.
- Apply fungicides (Bordeaux mixture/copper fungicides) to prevent infections.
- Harden plants in a shade house for 6–8 weeks before transplanting.
- Prune terminal bud after 6 months of transplanting to promote branching.

METHOD	ROOTSTOCK AGE	SCION AGE	SUCCESS RATE	ADVANTAGE	LIMITATION
Stone grafting	7- 15 days	8-12 cm	60-80 %	Cheap, easy, suitable for mass multiplication	Timing critical, scions must be fresh
Softwood grafting	6-12 months	8-12 cm	70-90 %	High success rate, promotes early growth	Requires skillful handling
Veneer grafting	1-2 year	8-12 cm	60-75%	Produces strong union, suitable for nurseries	More labour-intensive
Inarching	1 year	Growing shoot	50-60%	Produces very strong grafts	Very slow and labour-intensive
Side grafting	6-12 months	8-12 cm	60-70%	Simple method, adaptable to many varieties	Moderate success rate

ADVANTAGES OF GRAFTING IN MANGO

- Produces true-to-type plants.
- Induces early bearing (3–4 years).
- Allows mass propagation of superior varieties.
- Enables dwarf and high-density orchards.
- Improves adaptability and disease resistance via rootstock.

LIMITATIONS

- Skilled labour required.

- Grafted plants are more expensive than seedlings.
- Requires proper timing and aftercare.

Conclusion

Mango grafting is a dependable and widely practiced technique for producing true-to-type, high-yielding varieties. Among the methods, stone and softwood grafting are most common due to their high success rates, cost-effectiveness, and suitability for large-scale multiplication, while veneer and side grafting serve well in nursery practices requiring precision. Inarching, though durable, is slow and labour-intensive. The choice of method depends on local climate, availability of rootstock and scion material, and skill of the propagator. Overall, grafting preserves desirable genetic traits, ensures orchard uniformity, and accelerates productivity, making it a cornerstone of modern mango cultivation.

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DISEASE MANAGEMENT IN NURSERY

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Introduction

Plant nurseries plays major role in horticulture by producing high-quality seedlings and plants for commercial farms, landscaping, forestry, and home gardening. The major problems in nurseries is plant disease management. Diseases can reduce plant vigour, aesthetic value, and survival rates, directly impacting profitability and customer satisfaction. Effective disease management in nurseries requires a combination of knowledge, early detection, preventive measures, and integrated control strategies. This article explores the causes, common diseases, and best practices for managing plant diseases in nursery environments.

Common nursery diseases:

- ✓ Nurseries are particularly susceptible to diseases due to:
- ✓ High plant density
- ✓ Frequent watering
- ✓ Humid microclimates
- ✓ Repeated reuse of containers and soil
- ✓ Here are some common nursery diseases and their causal agents:

Disease Name	Pathogen Type	Causal Agent	Symptoms
Damping-off	Fungal/oomycete	*Pythium*, *Rhizoctonia*	Dull green color, drooping cotyledons, water-soaked lesions on

Disease Name	Pathogen Type	Causal Agent	Symptoms
			the stem
Powdery mildew	Fungal	*Erysiphe spp.*	White powdery patches on leaves
Leaf spot	Fungal/Bacterial	*Alternaria*, *Xanthomonas*	Brown or black circular lesions
Root rot	Fungal	*Phytophthora*, *Fusarium*	Wilting, yellowing or browning of leaves
Blight	Fungal	*Botrytis*, *Phytophthora*	Rapid tissue death in leaves/stems, browning of leaves

Damping off(Brinjal)

Powdery Mildew(tomato)

Leaf spot(bhendi)

root rot(chilli)

Leaf blight (Tomato)

Symptoms of disease

1. **Damping-off Disease** – The most common and serious disease in nurseries. Caused by fungi such as *Pythium*, *Rhizoctonia*, and *Fusarium*. Seedlings suddenly collapse near the soil line, leading to huge losses.
2. **Root Rot** – Caused by soil-borne fungi. Roots become brown and weak, making seedlings wilt.
3. **Leaf Spot Diseases** – Brown or black spots appear on leaves, reducing photosynthesis and seedling vigour.
4. **Powdery Mildew** – White, powdery growth on leaves, often seen in vegetable nurseries.
5. **Blights** – Sudden drying and death of leaves or stems.
6. **Viral Diseases** – Spread by insects like aphids, thrips, and whiteflies. Infected seedlings show yellowing, curling, or mosaic patterns on leaves.

Several factors causes disease

- ✓ High humidity and poor air circulation
- ✓ Overwatering or waterlogging
- ✓ Lack of sunlight in dense shade
- ✓ Reuse of infected soil or pots
- ✓ Contaminated water sources
- ✓ Poorly disinfected tools and benches
- ✓ Overcrowding of plants
- ✓ Use of susceptible or untreated plant material
- ✓ Stress from nutrient deficiencies or pests

Disease diagnosis:

- ✓ Hand lenses or digital microscopes
- ✓ Sticky traps for insect vectors
- ✓ Disease identification apps (e.g., Plantix, Leaf Doctor)
- ✓ Laboratory diagnostic services for pathogen identification

Integrated Disease Management (IDM) in Nurseries

Cultural Practices

- ✓ Use sterilized soil or soilless media
- ✓ Clean and disinfect all tools, trays, and benches

- ✓ Ensure adequate spacing for airflow
- ✓ Rotate crops and avoid monoculture
- ✓ Remove diseased plants immediately

Chemical Control

- ✓ Apply fungicides preventively, not reactively
- ✓ Rotate fungicides to avoid resistance buildup
- ✓ Follow label instructions and pre-harvest intervals
- ✓ Use systemic and contact fungicides appropriately

Examples:

- ✓ Copper-based fungicides (for bacterial/fungal leaf spots)
- ✓ Mancozeb, Captan (broad-spectrum protection)
- ✓ Phosphonates for root rot (*Phytophthora*)

Biological Control

- ✓ Use beneficial microbes like *Trichoderma*, *Bacillus subtilis*
- ✓ Apply compost teas or microbial drenches to suppress soil pathogens
- ✓ Encourage natural enemies of disease vectors (e.g., predatory mites)

Environmental Control

- ✓ Use raised beds or benches to avoid soil-borne pathogens
- ✓ Regulate humidity through misting schedules and ventilation
- ✓ Avoid overhead watering if foliar diseases are present

Prevention measures

- ✓ Always select certified, disease-free seeds.
- ✓ Sterilize soil through solarization (covering with plastic sheets in the sun) or chemical treatment to kill hidden pathogens.
- ✓ Waterlogging encourages fungal growth; well-drained soil prevents root rot.
- ✓ Avoid overcrowding so air can circulate freely, reducing humidity.
- ✓ Nursery trays, containers, and tools must be disinfected regularly.

Training and Staff Awareness

- ✓ Many outbreaks are due to human error.
- ✓ Recognizing early signs of disease
- ✓ Proper tool hygiene

- ✓ Safe pesticide handling
- ✓ Importance of quarantine for new plant material

Conclusion

Disease management in nurseries is not just about saving seedlings it is about protecting the future of farming. A well-managed nursery produces strong, disease-free seedlings that grow into productive crops, ensuring food security, farmer income, and environmental balance. By combining prevention, hygiene, and modern Integrated Disease Management practices, we can keep nurseries healthy and thriving.

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IMPACT OF RUGOSE SPIRALLING WHITEFLY ON COCONUT AND OTHER CROPS

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Introduction

The Rugose Spiralling Whitefly ***(Aleurodicus rugioperculatus Martin***), family Aleyrodidae, is an exotic insect pest that has recently been recognized as a major threat to plantation crops, particularly coconut. It was originally described from Belize in 2004, subsequently reported from Florida in 2009, and from India for the first time in 2016 at Pollachi, Tamil Nadu. In a matter of few years, the pest infested all principal coconut-growing areas in South India and has been reported on a large variety of plantation crops. As compared to the general whiteflies, which will be present in low densities, the rugose spiralling whitefly can be seen to cover leaves and inflict extensive damage in high population numbers.

Biology and Identification

The pest oviposits in distinctive spiral circles on the underside of leaves, hence earning the common name "spiralling whitefly." The eggs have a waxy covering, which offers protection. Nymphs are immobile and stuck to the leaf surface, but adults are relatively bigger than typical whiteflies and are sluggish in their flight. One of the principal characteristics of infestation is honeydew excretion in large quantities, which spills on to leaves, fruits, and soil at the base of the tree.

Nature of Damage

On Coconut

The coconut (Cocos nucifera) is the most seriously damaged plantation crop.

Both nymph and adult suck sap from the lower surface of leaflets. The major symptoms are:

- Appearance of spiralling egg masses and dense colonies on leaves.
- Excessive secretion of honeydew resulting in sticky leaf surfaces.
- Overgrowth of black sooty mould on leaves and at times on bunches.
- Yellowing, photosynthesis reduction, and early drying of leaves.

Alternative hosts

The rugose spiraling whitefly is extremely polyphagous, reported on over 100 plant crops. Besides coconut, it infests:

Arecanut: Yellowing foliage, poor nut growth, and yields.

Banana: Infestation causes sticky leaves, decreased photosynthesis, and poor bunch quality.

Papaya: Honeydew and sooty mould render fruits unmarketable.

Guava and Mango: Heavy leaf coating with sooty mould lowers tree vigor and fruit yield.

Cashew and Coffee: Decreased photosynthesis, weak growth, and total loss of yield.

Ornamental plants: Aesthetic value loss due to discolored leaves and weak growth.

The pest is therefore a multi-crop pest, with the potential to cause serious losses on several plantation crops, hence jeopardizing the farmer's livelihood.

Economic Impact

The pest has both direct and indirect effect. The direct damage is due to sap sucking, reducing the plant's strength. But the indirect effect via sooty mould is more injurious:

Reduction in yield: In coconut, reduction in yield of 30–40% has been noticed in heavily infested regions.

Reduction in quality: Papaya, guava, and banana fruits become unappealing for marketing.

Management cost escalation: Farmers incur higher costs on pest control and plant protection operations.

Livelihood impact: Being key livelihood crops in South India, infestations directly decrease farmers' income.

Management Strategies

Biological Control

Parasitoids*:* ***Encarsia guadeloupae*** (Aphelinidae) has proved to be highly effective in controlling the pest in India.

Predators: Ladybird beetles (***Cryptolaemus montrouzieri),*** green lacewings (***Mallada boninensis),*** and spiders prey on various stages of the pest.

Green lacewing - ***Mallada boninensis***

Conservation and augmentation of these natural enemies prevent pest populations from getting out of control.

Cultural and Mechanical Methods

1. Cleaning and destruction of severely infested leaves.
2. Employment of high-pressure water jets for removal of honeydew and nymphs.
3. Use of neem oil 3% and fish oil rosin soap 25g/L for population reduction.
4. Shunning broad-spectrum insecticides to preserve beneficial insects.

Conclusion

The rugose spiralling whitefly has emerged quickly as a pest of national importance in India, especially of coconut and other plantation crops. Its invasive habits, high reproductive rate, and broad host base render it a potential threat. On coconut, it diminishes nut production, marketability, and palm health, whereas in other plantation crops it is responsible for economic and aesthetic losses.

Exclusive use of chemical insecticides is not effective and sustainable. Rather, environmentally friendly options like conservation and augmentation of natural enemies, neem-based formulations, and integrated pest management yield long-term solutions. Enhancement of farmer awareness and organized management action are important to minimizing the effect of this pest as well as the plantation-based economy of the tropics.

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THE ERGOT – HISTORY AND CONCEPT OF POISONING TO PHARMACY

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Abstract

Claviceps purpurea, the ergot fungus, is a parasitic ascomycete infecting cereals and grasses, particularly rye. It replaces host seeds with dark sclerotia containing potent alkaloids, historically responsible for ergotism outbreaks in humans and livestock. Documented since ancient Mesopotamia and China, ergotism—known as "St. Anthony's Fire"—manifested in gangrenous and convulsive forms, causing severe morbidity and mortality across Europe during the Middle Ages. The fungus produces three main alkaloid groups: clavines, lysergic acid amides, and ergopeptides, some with significant pharmacological value. Controlled derivatives such as ergometrine and ergotamine are used in obstetrics to prevent postpartum hemorrhage, in neurology to treat migraines, and in endocrinology for hormonal disorders. While ergot remains a potential agricultural hazard, modern food safety practices and regulated pharmaceutical production have minimized its risks. This review discusses its taxonomy, biology, historical significance, symptoms, and medicinal applications, illustrating the transformation of a deadly plant pathogen into an invaluable medicinal resource.

Introduction

Members of the ascomycetous fungal genus Claviceps infect over 600 species of monocotyledonous plants belonging to the Poaceae, Juncaceae, and Cyperaceae families, which include important agricultural crops like rye, wheat, barley, rice, corn, millet, and oats. Most of the 30-36 species in this group are known to have a specific and limited host range. Claviceps

purpurea (Fries ex Fries) Tulasne, the most recognized species in Europe, is a notable exception, as it can infect more than 400 plant species and causes a disease known as ergot. Their life cycles are intricate. Instead of producing seeds, sclerotia form in the place of seeds after a Claviceps spore has infected the flowers of grasses. Ryegrass is especially vulnerable due to its exposed flower structure. The ergot fungus infiltrates the flower ovary, leading to the formation of large quantities of conidia (asexual spores) that can invade grass florets. Ergot targets solely the ovary of cereal and grass plants, leaving other sections of the plant unharmed. Ultimately, it becomes visible as blackened sclerotia found within the husks of the florets. These compounds include the physiologically potent ergot alkaloids, which are tri- or tetracyclic derivatives of prenylated tryptophan, attributing great importance to the fungus. During the Middle Ages, widespread outbreaks of the disease known as St. Anthony's Fire were triggered by the ingestion of rye tainted with ergot.

History

While it has been suggested that the Eleusinian Mysteries of ancient Greece, dating back 4,000 years, may have involved ergot-induced visions, the earliest confirmed mentions of ergot's effects appear in Chinese records around 1100 BC, where it was utilized in obstetrics. A magical incantation discovered in a small temple in Mesopotamia from 1900-1700 BC referred to grain with abnormal infestations as mehru, and Sumerian clay tablets from the same era documented the reddening of moist grain as samona. Mentions of grain diseases can also be found in various Old Testament books of the Bible from 850-550 BC. In 322 BC, Aristotle theorized that warm vapors were responsible for the occurrence of grain rust. Around 286 BC, the Greeks determined that barley was more susceptible to rust diseases than wheat and that breezy fields had less rust than damp, shaded, low-lying ones. The earliest reported pandemic of ergotism occurred around 944-945 AD, when over 20,000 persons in the Aquitaine region of France (almost half of the population) died as a result of ergot poisoning. The "holy fire" is said to have killed some 40,000 people 50 years later. Every year on April 19th, Jerusalem celebrates the holy fire event. Throughout the 18th century, botanists considered ergot to be a "super" rye with an expanded kernel.

Scientists at Marburg University in 1597 noted that eating blighted rye grains frequently resulted in the appearance of ergotism symptoms while the growing seasons were moist and cold, which encouraged that blight. It was noted in 1630 that animals fed blighted grain

developed a disease resembling ergotism in humans. Lastly, Von Munchhausen identified ergot as a fungus in 1764, and by the end of the 18th century, animals had been shown to be poisoned for a century. By 1676, the ingestion of contaminated rye had been identified as the cause of ergotism. The significant ergotism epidemics in Europe in 1770 and 1777 served as the impetus for the introduction of laws in France and other countries.

Between 1926 and 1927, around 11,319 cases of ergotism were documented in a 506,000-person community at Sarapol, which is close to the Ural Mountains. In Manchester, England, 200 Jewish migrants were ill in 1928 after they ate rye bread made using rye cultivated in South Yorkshire. In the middle of August 1951, 230 residents of Pont Saint-Esprit, a well-known French vacation destination on the Rhone River, became ill after consuming tainted products from a nearby baker.

Symptoms of C. purpurea on Floral plants:

Honeydew, a yellow liquid that resembles syrup that appears between the glumes of the floret, is the first obvious symptom of an ergot infection in plants. Later, purplish-black sclerotia, also referred to as ergot, replaces the honeydew phase. Typically ranging from 2 to 20

mm in length, sclerotia are packed with white mycelia. Sclerotium can grow up to five times larger than host seeds, depending on the host plant.

ERGOT IN RYE

Ergot poisoning:

Throughout the Middle Ages, outbreaks of ergot poisoning, sometimes known as ergotism, plagued continental Europe. In Germany, ergotism epidemics took place in 1581, 1587, and 1596. The fact that rye was cultivated in greater amounts during the Middle Ages and that many people, especially the less fortunate, consumed tainted rye flour contributed to these outbreaks. Due to the impact of the alkaloids produced by the parasitic ergot fungus that was

housed within the ergot fungal body (sclerotium), these outbreaks were characterized by the creation of two different forms of hazardous reactions.

Ergotismus gangrenous, the first gangrenous variety, was more prevalent in France and is often referred to as "holy fire," "infernal fire," or "St. Anthony's Fire. "Whole limbs, hands, and feet would expand, causing a sharp, searing sensation that finally led to the painless, bloodless separation of a dry gangrenous limb (often a foot) at a joint.St. Anthony's Fire got its name because, in the Middle Ages, the Order of St. Anthony provided care for those who suffered from the condition, which was typified by excruciating scorching pain (or "fire").Gangrenous ergotism outbreaks were documented between the Middle Ages and the 1800s.

Between 1581 and 1928, there were reported outbreaks of the second type of ergotism, commonly referred to as the convulsive form (*Ergotismus convulsivus*), which was especially prevalent in Germany. It was usually marked by the onset of hallucinations, along with acute diarrhea, muscle spasms, convulsions, and rigid, excruciatingly painful flexed limbs. Livestock feed contamination by ergot alkaloids has long been recognized and documented in a number of locations.Agalactia, gangrenous ergotism, and nervous ergotism are the three disorders that have been identified in animals.

Medicinal uses:

In France, Germany, and the US, ergot was widely used as an oxytocic during labor. The American doctor John Stearns documented the uterine contractile effects of a preparation of ergot made from blackened granary rye as a treatment for "quickening childbirth" in 1808, marking the drug's first acknowledged medical usage. Ergot was advised to be used exclusively to treat postpartum hemorrhage in 1824.

The greatest class of nitrogenous fungal metabolites observed in nature are the ergot alkaloids, which are indole chemicals that are biosynthetically produced from L-tryptophan. More than 80 distinct ergot alkaloids have been identified, mostly from different Claviceps species (more than 70 alkaloids), but also from higher plants and other fungi. About 0.15% to 0.5% of ergot sclerotia are alkaloids, and the substances that are valuable for medicine are divided into two classes: water-soluble amino alcohol derivatives and water-insoluble peptide derivatives. These alkaloids can be easily categorized into three main structural groups: peptides (also known as ergo peptides or ergopeptines), lysergic acid amides (paspalic acid amides), and clavines.

Though certain members, like the chanoclavines, have a 6,7-seco D-ring, the majority of the clavines are substituted 6,8-dimethylergolines.None of the group's alkaloids are used medicinally, despite the fact that at least 35 of them have been identified and isolated. Simple nonpeptidic amides are created when lysergic acid's C-8 carboxy group is amided.Ergonovine (ergometrine, ergobasine), lysergic acid 2-hydroxyethylamide, lysergic acid amide (ergine), and paspalic acid are common 5R,8R-nonpeptidic amides present in ergot.Ergonovine and its semisynthetic derivatives, methylergonovine and methysergide, are used medicinally, and amides produced from lysergic acid have a high pharmacological activity.

Ergotamine and dihydroergotamine are vasoconstrictors used to treat acute migraine attacks. They function by blocking inflammatory neuropeptides and narrowing dilated cerebral blood arteries. By inducing a forceful, prolonged contraction of the uterus, ergometrine (ergonovine) helps limit bleeding following childbirth or abortion and is used to prevent or treat postpartum hemorrhage. By activating dopamine receptors, certain ergot derivatives (such as pergolide and bromocriptine) function as dopamine agonists, which are used to treat Parkinson's disease symptoms like stiffness and tremors.In addition to lowering prolactin levels, bromocriptine is used to treat acromegaly (excess growth hormone), pituitary tumors that secrete prolactin, hyperprolactinemia (high prolactin causing menstruation problems or infertility), and a few other endocrine disorders.

Conclusion

Ergot fungus (*Claviceps purpurea*) stands as one of the most remarkable examples of how a single organism can influence human health, agriculture, and medicine over centuries. Historically feared as the cause of devastating epidemics of ergotism—responsible for severe gangrenous and convulsive symptoms—it shaped medieval society, influenced religious and cultural practices, and prompted the earliest forms of food safety legislation. Its life cycle, adapted to parasitize the floral ovaries of cereals and grasses, not only threatens crop productivity but also poses serious risks to human and animal health through contamination of food and feed. Yet, the same toxic alkaloids responsible for mass poisonings have been harnessed into potent pharmaceuticals. From controlling postpartum hemorrhage and inducing labor to treating migraines, Parkinson's disease, and endocrine disorders, ergot derived compounds demonstrate the delicate balance between toxicity and therapy. This transformation from a lethal contaminant to a valuable medicinal resource highlights the importance of scientific

investigation, regulation, and agricultural vigilance. Today, with advanced grain inspection, fungal biology research, and controlled pharmaceutical production, ergot serves as both a historical lesson in the dangers of foodborne toxins and a modern testament to the therapeutic potential hidden within nature's most dangerous.

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THE EVOLUTION AND INNOVATION OF YOGURT: FROM TRADITION TO FUNCTIONAL FOOD

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Abstract

Yogurt has evolved from a naturally fermented milk product to a functional food rich in probiotics and bioactive compounds. Advances in microbiology, technology, and ingredient formulation have enhanced its nutritional and sensory qualities. In a comparative analysis of two yogurt samples, Yogurt B demonstrated superior physicochemical and sensory properties, including higher protein and fat content, greater acidity, and better texture, flavour , and overall acceptability scores. These improvements highlight the impact of formulation and processing on yogurt quality. This review explores the historical evolution, modern innovations, and health benefits of yogurt, underscoring its transition into a complex, health-promoting product.

Keywords:

Yogurt evolution; Functional food; Probiotics; Fermentation technology; Sensory properties; Microbial cultures; Plant-based yogurt; Synbiotics; Bioactive compounds; Shelf life; Quality control; Gut health; Sustainable packaging; Fortification

Introduction

Yogurt, one of the most widely consumed fermented dairy products, has transcended centuries of tradition to become a modern symbol of health and nutrition. With its origins dating back over 8,000 years in Mesopotamia and Egypt, yogurt was initially a result of natural milk fermentation caused by environmental bacteria (Dahiya & Kaur, 2021). Over time, this

accidental discovery evolved into an intentional practice embraced by cultures across the Middle East, Central Asia, and Europe. Today, yogurt is consumed in a variety of forms—from thick Greek-style yogurt to drinkable and plant-based alternatives—and is lauded not just for its taste and texture but also for its impressive nutritional and therapeutic benefits (Pannerchelvan et al., 2024).

Microbiology and Probiotic Cultures

The fermentation of lactose by helpful bacteria forms the biological basis of yogurt manufacture. *Streptococcus thermophilus* and *Lactobacillus delbrueckii* subsp. *bulgaricus* are the typical strains used in yogurt production. These bacteria operate synergistically, transforming lactose into lactic acid, which gives yogurt its distinctive tangy flavor and lowers the pH of milk, causing it to coagulate and produce a soft gel (Dahiya & Kaur, 2021). In addition to these traditional strains, contemporary yogurt frequently contains other probiotic bacteria such as *Bifidobacterium lactis*, *Lactobacillus acidophilus*, *L. casei*, and *L. plantarum*. These probiotics have several health benefits, such as improved digestion, a better immune response, and less inflammation (Gomes & Malcata, 2021). They are frequently included in functional yogurts designed for particular health issues and also help regulate gut microbiota (Zhao & Shah, 2021).

Manufacturing Process and Ingredients

Milk standardization, in which the fat and protein content are modified to match the target product profile, is the first step in the yogurt production process. The next step is pasteurization and homogenization, which kill dangerous microorganisms and improve the creaminess of the finished product. The milk is inoculated with selected bacterial cultures once it has cooled, then kept at a regulated temperature until the necessary acidity is attained. Depending on the packaging technique employed, the outcome might be a set or stirred yogurt (Almeida et al., 2022). The procedure now covers a wide range of substrates, including goat milk, buffalo milk, soy milk, oat milk, cashew milk, and even unique blends like potato juice and cow milk (Wang et al., 2023). These modifications are particularly helpful for people who follow a plant-based diet or are lactose intolerant. Using components like pea protein, carboxymethyl cellulose, or seaweed-derived hydrocolloids, plant-based substitutes frequently need stabilizers and protein enrichment to replicate the creamy texture of dairy-based yogurt (Wang et al., 2023).

Technological Enhancements

Enzymatic approaches to improve yogurt quality have been brought about by modern technological interventions. Transglutaminase is one significant enzyme that enhances the protein network in yogurt, resulting in increased viscosity and decreased whey separation (El-Sayed & Hassan, 2020). Additional enzymes, such as protease and amylase, aid in the breakdown of proteins and the development of flavor. In the meantime, novel non-thermal processing techniques like high-pressure homogenization, ultrasound, and pulsed-electric fields are becoming more widely used to enhance the texture, microbial safety, and nutritional retention of yogurt without sacrificing taste or freshness (Liu & Li, 2023).

Physicochemical and Sensory Properties

The quality of yogurt depends primarily on its physicochemical and sensory characteristics. The perfect yogurt should have a consistent thickness, a creamy, smooth texture, and a good mix of sourness and natural sweetness (Rahman et al., 2024). These attributes are affected by critical factors like moisture levels, protein and fat content, acidity, pH, and total solids. Taste panels are used to conduct sensory evaluations to determine texture, aroma, flavor intensity, and aftertaste in order to verify that the product satisfies consumer expectations (Almeida et al., 2022). To illustrate these attributes, two yogurt samples—Yogurt A and Yogurt B—were analyzed and compared based on pH, titratable acidity, moisture, protein, and fat content, as well as sensory scores for texture, flavor, and overall acceptability. The results are summarized in Table 1 below.

In comparing the two yogurt samples, Yogurt B demonstrates superior quality in several key aspects. It has a slightly lower pH and higher titratable acidity, which contributes to a tangier flavor preferred by many consumers. Additionally, Yogurt B shows higher protein and fat contents, enhancing its nutritional value and creaminess. Sensory evaluation scores also favor Yogurt B, with better texture (9/10), flavor (8/10), and overall acceptability (9/10) compared to Yogurt A. These attributes indicate that Yogurt B offers an improved balance of physicochemical properties and sensory appeal, making it the preferred choice in this comparison (Almeida et al., 2022; Rahman et al., 2024).

Table 1. Comparative Physicochemical and Sensory Properties of Two Yogurt Samples

Sample	Yogurt A	Yogurt B
pH	4.5	4.3
Titratable acidity (%)	0.85	0.90
Moisture content(%)	85.0	83.5
Protein content(%)	3.5	3.8
Fat content(%)	3.0	3.2
Texture score(10)	8	9
Flavour score(10)	7	8
Overall Acceptability(10)	8	9

Functional Fortification and Bioactive Additions

In order to improve its functionality, yogurt is now frequently fortified with additional components, such as prebiotics (like inulin), dietary fiber, and organic antioxidants obtained from cocoa, turmeric, green tea, or saffron (Kumar & Kumar, 2022). In addition to enhancing flavor and texture, these substances have antioxidant and anti-inflammatory effects. The combination of prebiotics and probiotics in yogurt produces a synbiotic impact, which has been proven in clinical studies to lower oxidative stress, improve immunological markers, and promote gut health (Zhao & Shah, 2021). Encapsulation technologies have also grown in popularity due to their ability to protect probiotic bacteria during processing and ensure their survival in the intestinal tract (Kumar & Kumar, 2022).

Storage and Shelf Life

Effective storage and shelf-life management are critical to maintaining yogurt quality and probiotic viability. Refrigerated yogurt must be stored at 4–6°C to ensure microbial viability and prevent spoilage. Despite refrigeration, yogurt undergoes biochemical changes over time, including increased acidity and texture changes. Freeze-drying or spray-drying starter cultures

has become a popular method to enhance microbial shelf-stability (Iqbal et al., 2024). Proper packaging—typically foil-sealed containers—is also essential to avoid oxygen exposure and microbial contamination.

Spoilage and Quality Control

Yogurt can still spoil despite its low pH if hygiene and production controls are lacking. Contamination can result from poor raw milk quality, unhygienic equipment, or mishandling. Common spoilage organisms include *Saccharomyces cerevisiae*, *Aspergillus*, *Penicillium*, and lactic acid bacteria (Martínez-Ruiz & López-Malo, 2020). These contaminants can cause off-flavors, discoloration, and textural defects. Thus, strict quality assurance procedures are essential throughout yogurt production (Martínez-Ruiz & López-Malo, 2020).

Health Benefits and Functional Claims

Yogurt is increasingly recognized as a functional food due to its health-promoting properties. Regular consumption has been linked to improved digestion, reduced inflammation, and a lower risk of chronic diseases (Pannerchelvan et al., 2024). Epidemiological studies show that individuals consuming yogurt at least twice weekly may have a reduced risk of colorectal cancer (Gomes & Malcata, 2021). Synbiotic yogurts have also demonstrated benefits in lowering blood pressure and LDL cholesterol while improving mood through the gut-brain axis (Zhao & Shah, 2021).

Future Innovations and Sustainability

The future of yogurt manufacturing is moving toward precision nutrition, with innovations such as bioactive peptides, personalized microbiome-targeted products, and fortified plant-based ingredients (Zhang et al., 2023). Technologies like microfluidization and advanced encapsulation will further enhance functionality. Sustainability is another emerging focus, with producers seeking to reduce food waste, recycle byproducts like whey, and adopt biodegradable packaging (Iqbal et al., 2024).

Conclusion

Yogurt's journey from an ancient, naturally fermented dairy product to a scientifically enhanced functional food highlights the dynamic intersection of tradition and innovation. Advances in microbial strains, fermentation technology, and ingredient diversification have expanded yogurt's nutritional and therapeutic potential, making it a vital part of modern diets worldwide. The integration of probiotics, prebiotics, and bioactive compounds has transformed

yogurt into a powerful ally for gut health, immunity, and chronic disease prevention. Moreover, emerging technologies and sustainable practices promise to further elevate yogurt's quality, safety, and environmental impact. As consumer demand for personalized nutrition and health-promoting foods grows, yogurt's evolution will continue, balancing its rich heritage with cutting-edge science to meet the needs of future generations.

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DIETARY RESTRICTIONS AND THEIR INFLUENCE ON FLAVORED YOGURT DEVELOPMENT

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Abstract

Evolving consumer dietary patterns are reshaping the flavored yogurt industry. Increased awareness of lactose intolerance, gluten sensitivity, food allergies, and lifestyle-driven choices such as veganism and reduced sugar intake is prompting manufacturers to rethink traditional yogurt formulations. This article examines how these dietary limitations are driving the innovation of new yogurt varieties, including lactose-free, plant-based, gluten-free, and allergen-conscious alternatives. It explores the integration of non-dairy bases like almond, soy, oat, and coconut milk in vegan options, along with the use of natural sweeteners as sugar substitutes. Although recreating the texture and taste of conventional dairy yogurt poses challenges, ongoing advancements in food technology are enabling producers to meet the needs of modern, health-conscious consumers. The article concludes that as personalized nutrition continues to gain traction, flavored yogurt remains a dynamic and adaptive segment of the food market.

INTRODUCTION

Yogurt has long been recognized as a staple in global diets, valued for its creamy consistency and probiotic qualities. However, evolving dietary trends and increasing health awareness are changing both the composition and consumption of yogurt products. More individuals are seeking alternatives to dairy due to lactose intolerance, ethical concerns, or personal health goals. These shifts have encouraged significant innovation within the flavored

yogurt category, giving rise to lactose-free, non-dairy, and plant-based options. For example, studies have shown that expanding yogurt varieties can increase consumption among children (Zhu & Hollis, 2014), highlighting the importance of product innovation.

LACTOSE INTOLERANCE AND THE EXPANSION OF LACTOSE-FREE YOGURTS

A significant portion of the world's population estimated at approximately 68% experiences difficulty digesting lactose, the primary sugar found in milk (NIH, 2020). This condition, known as lactose intolerance, can cause gastrointestinal discomfort such as bloating and cramps following the consumption of dairy.

To accommodate these consumers, many yogurt brands have developed lactose-free offerings. These products are typically treated with lactase enzymes, which pre-digest lactose, making the yogurt more suitable for sensitive individuals. Such innovations ensure that yogurt remains accessible to wider consumer groups while preserving its nutritional and probiotic value.

Flavored Lactose-Free Yogurt Options

Flavored varieties, including vanilla, mixed berries, and tropical blends, have enhanced accessibility for those with lactose intolerance, allowing them to enjoy the taste and benefits of yogurt without discomfort. The fermentation process, which naturally reduces lactose levels, also contributes to the improved digestibility of these products.

Production Challenges and Technological Solutions

Replicating the rich texture and flavor of traditional yogurt in lactose-free alternatives is a notable challenge. Manufacturers often rely on added probiotics, thickeners, and stabilizers such as pectin or agar to emulate the creamy consistency that consumers expect.

PLANT-BASED DIETS AND THE RISE OF VEGAN YOGURTS

The increasing adoption of plant-based and vegan diets is a powerful force behind the transformation of the yogurt market. Individuals who avoid animal products require dairy-free alternatives, leading to the development of yogurts made from plant-derived milks. Current literature highlights that dairy-free alternatives are one of the most dynamic and challenging areas of yogurt development (Rojas-Rivas & Gutiérrez-Cortez, 2021).

Common Plant-Based Milk Bases

- **Almond Milk:** Offers a light, nutty profile that pairs well with fruit and spice flavors.
- **Coconut Milk:** Known for its richness, it complements tropical or dessert-inspired flavors.

- **Soy Milk:** High in protein and neutral in flavor, making it a flexible base for a range of tastes.
- **Oat Milk:** Naturally sweet and creamy, ideal for dessert-like yogurt variations.

Vegan Flavored Yogurt Innovation

Today's vegan yogurts feature both classic flavors (e.g., blueberry, peach) and inventive combinations such as turmeric-ginger or chocolate-hazelnut. Advances in formulation have improved their texture, making them increasingly indistinguishable from dairy-based yogurts.

Addressing Taste and Texture Challenges

Different plant milks have distinct protein and fat profiles, making consistency difficult to standardize. Producers use techniques such as starch addition, emulsifiers, and flavor-masking agents to overcome issues like thin texture or aftertaste.

GLUTEN-FREE AND ALLERGEN-FRIENDLY YOGURT OPTIONS

Dietary restrictions related to gluten and food allergies are also influencing product development. Although plain yogurt is naturally gluten-free, flavored products may contain additives or thickeners derived from gluten-containing grains.

Gluten-Free Flavored Yogurts

To ensure safety for individuals with celiac disease or gluten sensitivity, manufacturers are now offering certified gluten-free yogurts. This involves vetting all ingredients and ensuring no cross-contamination during production.

Nut-Free and Allergy-Sensitive Options

Given the rising prevalence of food allergies particularly to nuts some producers have begun crafting yogurt options that are free from common allergens. This includes plant-based yogurts made without nuts, ideal for those with dietary limitations.

Maintaining Allergen Safety Standards

To protect sensitive consumers, facilities must enforce stringent allergen control measures. These include dedicated equipment, detailed labeling, and rigorous cleaning protocols to prevent cross-contact.

NATURAL SWEETENERS AND REDUCED SUGAR YOGURTS

In response to health concerns about added sugar, many consumers now seek yogurts with reduced or no sugar content. This demand has encouraged producers to use natural sweeteners that do not impact blood glucose levels significantly. Research shows that consumer acceptance

of reduced-sugar yogurt is highly dependent on taste balance and formulation strategies (Ares & Varela, 2021).

Popular Natural Sweetener Alternatives

- **Stevia:** Plant-based and calorie-free, commonly used in health-conscious products.
- **Monk Fruit Extract:** Naturally sweet with a low glycemic impact.
- **Agave Syrup:** Sweeter than sugar and often used in moderation to enhance flavor.

These sweeteners allow flavored yogurts to maintain a palatable taste while aligning with dietary goals such as blood sugar management or calorie reduction.

Nutrient-Enriched Functional Yogurts

Beyond sweetness, many flavored yogurts now incorporate added nutrients such as fiber, protein, and vitamins. These functional enhancements appeal to consumers interested in wellness and performance nutrition.

Conclusion

Dietary restrictions are significantly reshaping the flavored yogurt landscape. The increasing demand for lactose-free, vegan, gluten-free, and low-sugar products is driving producers to innovate in both formulation and manufacturing. While challenges remain particularly in replicating the flavor and texture of traditional yogurt advances in ingredients and processing methods are enabling broader consumer access. As personalization and health consciousness continue to shape the food industry, flavored yogurt is well-positioned to remain a flexible, inclusive, and forward-thinking product category.

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MINIATURE REVOLUTION IN INDIAN AGRICULTURE

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Abstract

The term "Miniature Revolution" itself might not be universally established, the concepts underlying this movement align closely with developments in agro ecology, regenerative agriculture, local food systems, and the revaluation of small-scale farming in the context of sustainability and resilience. Agriculture, the backbone of human civilization, has witnessed significant transformations over millennia and contributing significantly to the country's GDP. However, the sector has faced numerous challenges, including fragmented land holdings, inadequate infrastructure, and dependency on traditional farming methods. The contemporary world is experiencing a miniature revolution in agriculture, driven by technological advancements, environmental concerns, and socio-economic factors. This revaluation encompasses innovative practices, sustainable methods, and digital solutions aimed at enhancing productivity, preserving resources, and ensuring food security. In this discourse, we delve into the multifaceted dimensions of this miniature revolution in agriculture, exploring its drivers, impacts, challenges, and future prospects.

Key words: Agriculture, Revaluation, Ecosystem, Ecology, Sustainability

Introduction

The "Miniature Revolution" in agriculture is a multifaceted shift toward small-scale, sustainable, and highly productive farming systems. The history of **agriculture in India** dates back to the Neolithic period. India ranks second worldwide in farm outputs. As per the Indian economic survey 2020 - 21, agriculture employed more than 50% of the Indian workforce and contributed 20.2% to the country's GDP (Anonymous, 2018). In 2016, agriculture and allied sectors like animal husbandry, forestry and fisheries accounted for 17.5% of the GDP (gross domestic product) with about 41.49% of the workforce in 2020. (Anonymous, 2015, 2018, 2019,2020, 2021 & 2024). India ranks first in the world with highest net cropped area followed by US and China (Anonymous, 2018). The economic contribution of agriculture to India's GDP is steadily declining with the country's broad-based economic growth. Still, agriculture is demographically the broadest economic sector and plays a significant role in the overall socio-economic fabric of India. The idea of a "Miniature Revolution" in agriculture, particularly in terms of sustainable and small-scale farming practices also may be play vital role, is an emerging paradigm that has gained significant attention in recent years. While the term itself might not be universally established, the concepts underlying this movement align closely with developments in agro ecology, regenerative agriculture, local food systems, and the revaluation of small-scale farming in the context of sustainability and resilience. Below is a more detailed exploration of the various aspects of this "Miniature Revolution," accompanied by references to key literature and studies that support these ideas.

1. Small-Scale, High-Yield Agriculture

Small-scale agriculture can often outperform industrial farming in terms of land use efficiency and sustainability, especially when high-intensity, diversified, and organic methods are employed.

Market Gardening & Intensive Cropping: High-density, small-scale farming has been proven to yield more per unit of land than industrial-scale monocultures. The work of John Jeavons on biointensive gardening (Jeavons, J. How to Grow More Vegetables 1991) highlights methods that emphasize high-efficiency farming with minimal space.

Agro ecology: This approach incorporates ecological principles into farming to increase sustainability and biodiversity. Research by Altieri (2002) argues that agroecological methods can increase the resilience and productivity of small farms. Altieri's studies in Latin America

show that agro ecology, when scaled to smallholder farms, can reduce pesticide use and increase biodiversity.

2. Localizing Food Systems

One of the most striking features of the "Miniature Revolution" is the growing shift toward local food systems, particularly in urban areas where food production is decentralized, and direct-to-consumer models thrive.

Urban Agriculture: Studies show that urban agriculture can significantly contribute to food security while reducing the carbon footprint of food transportation. Mougeot (2005) explores the role of urban agriculture in the global South, where it provides not only food security but also employment and social capital.

Farmers' Markets and CSAs: These models enhance the connection between consumers and producers, allowing for fresher, locally grown food and fairer pricing. Feenstra (1997) discusses the importance of local food systems in strengthening rural economies and building more sustainable communities.

3. Regenerative Agriculture

Regenerative agriculture is one of the key practices promoted in the "Miniature Revolution." It focuses on rebuilding soil health, enhancing biodiversity, and restoring ecosystem functions rather than merely sustaining current agricultural systems.

No-Till Farming: Research by Derpsch (2009) demonstrates that no-till practices can increase soil carbon sequestration, reduce erosion, and enhance soil health, which are especially beneficial for small-scale farmers in terms of cost and environmental sustainability.

Agro forestry and Poly cultures: Small farms that integrate trees and other plants in agro forestry systems can benefit from increased resilience to climate change, improved soil health, and diversified income streams. Nair (2012) provides a comprehensive overview of how agro forestry systems support biodiversity and enhance farm productivity.

4. Technology and Innovation for Small Farmers

Technology is increasingly democratized and accessible to small-scale farmers, which allows them to adopt sustainable practices without sacrificing productivity.

Precision Agriculture: Wolfert et al. (2017) explore how precision farming technologies, like drones and sensors, can be adapted to small-scale farms, offering insights into yield prediction and resource optimization.

Mobile Apps for Farmers: The development of mobile technologies for small-scale farmers, such as agricultural extension services via smart phones, has proven to be a game-changer. Aker (2011) demonstrates how mobile phones are transforming access to market information and agricultural knowledge in rural Africa.

5. Sustainability and Environmental Impact

The environmental benefits of small-scale, regenerative farming systems are a core feature of the miniature revolution. These practices contribute to biodiversity, reduce chemical use, and mitigate climate change.

Water Conservation and Efficient Irrigation: The adoption of low-tech but efficient water conservation systems like drip irrigation has been shown to reduce water consumption significantly in smallholder farms. Postel (2000) discusses the importance of water conservation strategies in sustainable agriculture.

Organic and Biodynamic Farming: Organic farming practices that avoid synthetic fertilizers and pesticides are particularly aligned with small-scale farming models. Gomiero et al. (2011) review how organic farming benefits both the environment and human health.

6. Empowerment and Community Building

Small-scale, localized farming often fosters stronger communities and can contribute to social justice by empowering farmers, particularly marginalized groups.

Food Sovereignty: Patel (2009) advocates for food sovereignty as a key framework for empowering communities to reclaim control over their food systems. Small farms that embrace food sovereignty are less dependent on global markets and better able to resist external pressures.

Cooperatives: Farmer cooperatives and community-supported agriculture (CSA) initiatives play a vital role in supporting small-scale farmers, enabling them to share resources, access markets, and reduce costs. Barton (2014) outlines how farmer cooperatives enhance social capital and resilience in rural communities.

7. Economic Revaluation and Policy Support

The "Miniature Revolution" in agriculture also involves a shift in policy, where governments and organizations begin to recognize the value of small holder farming as essential to food security and ecological sustainability.

Subsidies and Incentives for Sustainability: In countries like the United States, policy incentives for regenerative agriculture are beginning to gain ground. Lyon (2015) discusses how

agricultural policy can encourage sustainable practices and the shift from industrial farming to ecological models.

Fair Trade: The rise of fair trade and ethical sourcing in agriculture has empowered small farmers by ensuring they receive a fair price for their products. Nicholls and Opal (2005) explore the growth of the fair trade movement and its impact on smallholder economies.

8. Government Policies and Programs:

PM-KISAN: Detail the direct income support scheme for farmers and its impact on rural livelihoods and purchasing power.

PMKSY and RKVY: Explain how these schemes promote efficient water use, infrastructure development, and agricultural diversification at the state level.

Soil Health Card Scheme: Discuss the significance of soil testing, nutrient management, and balanced fertilization in improving soil health and crop productivity.

NMSA: Highlight the objectives of promoting sustainable agriculture, enhancing resilience to climate change, and supporting organic farming practices.

9. Impact on Farmers and Economy:

1. Enhanced Productivity:

- Optimal resource utilization and precision farming techniques leading to increased yields.
- Adoption of high-tech equipment and machinery streamlining agricultural operations.
- Introduction of genetically modified crops resistant to pests, diseases, and adverse environmental conditions.

2. Resource Conservation:

- Conservation tillage practices minimizing soil erosion and preserving soil fertility.
- Efficient water management through drip irrigation, rainwater harvesting, and smart irrigation systems.
- Reduction in chemical inputs mitigating environmental pollution and promoting ecological balance.

3. Socio-Economic Development:

- Empowerment of smallholder farmers through access to technology, knowledge, and markets.
- Creation of rural employment opportunities in agri-tech startups and related industries.

- Strengthening of food security by promoting local food production and reducing dependency on imports.
- Mitigating the risk of marginalization of traditional farming communities in the face of rapid technological changes.

Challenges:

1. Technological Divide:

- Unequal access to technology and digital infrastructure among small-scale farmers.
- Affordability constraints hindering the adoption of high-tech solutions in resource-constrained regions.

2. Environmental Sustainability:

- Balancing technological interventions with ecological conservation and biodiversity preservation.
- Addressing concerns regarding the long-term impacts of genetically modified organisms (GMOs) on ecosystems.

3. Socio-Economic Equity:

- Ensuring that the benefits of agricultural revaluation are equitably distributed among all stakeholders.
- Mitigating the risk of marginalization of traditional farming communities in the face of rapid technological changes.

Case Studies and Success Stories:

- **Precision Farming:** Profile farmers or communities that have successfully implemented precision agriculture techniques and share their experiences, challenges, and outcomes.
- **Community-led Initiatives:** Showcase grassroots initiatives or farmer cooperatives that have transformed local agriculture through collective action, knowledge sharing, and resource mobilization.
- **Government-NGO Partnerships:** Highlight collaborative projects between government agencies, NGOs, and research institutions aimed at promoting sustainable agriculture, empowering farmers, and improving livelihoods.
- **Women in Agriculture:** Feature stories of women farmers breaking barriers, innovating in agriculture, and driving positive change in their communities, with a focus on gender-inclusive policies and programs.

Future Prospects:

1. Integration of Artificial Intelligence (AI) and Big Data Analytics:

- Harnessing AI algorithms and predictive analytics for more informed decision-making in agriculture.
- Leveraging Big Data to optimize supply chains, predict market trends, and mitigate risks.

2. Climate-smart Agriculture:

- Development of climate-resilient crop varieties capable of withstanding extreme weather events.
- Implementation of adaptive farming practices to mitigate the impacts of climate change on agriculture.

3. Collaborative Partnerships:

- Collaboration between governments, private sector entities, research institutions, and grassroots organizations.
- Sharing of knowledge, resources, and best practices to foster innovation and sustainable development in agriculture.

Conclusion

The miniature revaluation in Indian agriculture signifies a multifaceted paradigm shift towards small-scale, a more sustainable, efficient, highly productive and inclusive farming system. While challenges persist, the concerted efforts of stakeholders are paving the way for a brighter future for Indian farmers and the agricultural sector as a whole. By embracing innovation, technology, and best practices, India can unlock the full potential of its agriculture and ensure food security, rural prosperity, and environmental sustainability for generations to come. This paradigm shift toward smaller, more sustainable farming systems promises a more resilient future for food production across the globe. The references provided above highlight key research and literature that support these trends, showing how smallholder farming can offer solutions to many of the challenges posed by industrial agriculture, such as environmental degradation, food insecurity, and social inequality.

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NEXT-GEN AGRICULTURE: THE MINI ROBOT REVOLUTION

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Introduction

Mini robots are small, often autonomous or semi-autonomous machines designed to perform specific agricultural tasks with high precision and efficiency. They are part of the precision agriculture revolution, aiming to reduce labor, optimize input use, and improve crop yields while minimizing environmental impact. By automating different tasks, increasing productivity, and using fewer resources, small robots also known as agricultural robots are revolutionizing the agricultural industry. These robots can manage livestock and perform precision planting, harvesting, weeding, and pest control duties because they are frequently outfitted with sophisticated sensors and artificial intelligence.

Key Applications

1. **Weed Control**
    - Robots like *Ecorobotix* or *Oz* identify and remove weeds using computer vision and mechanical arms or micro-sprayers, reducing herbicide use.
2. **Planting & Seeding**
    - Mini robots can plant seeds in exact locations and depths, ensuring optimal germination and uniform growth.
3. **Crop Monitoring**
    - Equipped with cameras, multispectral sensors, and AI algorithms, they collect data on crop health, pests, and diseases.

4. **Precision Spraying**
    - Targeted spraying of fertilizers or pesticides directly onto plants instead of blanket application, saving costs and reducing pollution.
5. **Harvesting**
    - Soft-grip harvesting robots for delicate crops like strawberries or tomatoes can work continuously and reduce damage.
6. **Soil Analysis**
    - Mini robots can take soil samples and provide real-time data on moisture, nutrients, and pH for better crop management.

Advantages

- **Reduced Labor Dependence** – Can work 24/7 without fatigue.
- **Precision & Efficiency** – Minimizes input waste and maximizes yield.
- **Sustainability** – Less chemical use and better resource management.
- **Accessibility** – Small size allows use in greenhouses, orchards, and row crops where large tractors can't go.

Challenges

- **High Initial Cost** – May be unaffordable for small farmers without subsidies.
- **Maintenance & Repairs** – Requires technical skills and spare parts.
- **Connectivity** – Often depends on high-speed internet (future 6G could solve this).
- **Battery Life** – Limited operational hours without frequent charging.

Examples of Mini Agricultural Robots

Ecorobotix - Solar-powered weed control

Farm Bot - Open-source precision farming platform

Oz- Weeding and light tillage

Terra Sentia- Row crop phenotyping and monitoring

Robo crop- Automated weeding for vegetables

Importance of Mini Robots in Agriculture

- **High Precision, Low Waste:** They can target specific plants—be it for spraying, weeding, or monitoring—dramatically reducing chemical use and waste.
- **Soil Preservation:** Their lightweight design reduces soil compaction compared to heavy traditional machinery.

- **Ideal for Smallholder Farms:** Compact, modular, and often app-controlled, they're ideal for small plots, greenhouses, or farms with complex layouts.
- **Sustainable Practices:** Many use solar power or target solutions (like electric weeding or air-based pollination), supporting eco-friendly agriculture.
- **Accessible Maintenance:** Companies like Swarm Farm promote farmer-friendly maintenance and modular design to reduce downtime and costs.

Figure 1. Mini Robots in Agricultural field

By automating different tasks, increasing productivity, and using fewer resources, small robots also known as agricultural robots are revolutionizing the agricultural industry. These robots can manage livestock and perform precision planting, harvesting, weeding, and pest control duties because they are frequently outfitted with sophisticated sensors and artificial intelligence.

In contrast to current methods, known as "spray and pray," which waste 95% to 99% of pesticides and herbicides because they are applied to entire fields, robots stationed in the fields

would be able to target pesticides to the plants that need them. Although the majority of this is wasted, it encourages weed and pest resistance, making harsh chemicals useless and pushing farmers to use more. The use of certain pesticides in this manner has been outlawed because they are detrimental to pollinators like bees. The seeds of a robotic-greenhouse future are being sown by a number of startups. Although not all crops can be grown in this manner, the benefits are noticeable for some. These companies boast controlled indoor environments that eliminate the need for pesticides and promise a dramatic reduction in water usage of 90 to 95 percent for an equivalent crop yield.

Conclusion

Robotics in agriculture is rapidly transforming traditional farming into a highly efficient, precise, and sustainable system. By automating labor-intensive tasks such as planting, weeding, harvesting, and crop monitoring, agricultural robots reduce dependence on manual labor, minimize human error, and enhance productivity. These technologies also promote resource efficiency by optimizing inputs like water, fertilizers, and pesticides, contributing to environmental sustainability. While challenges such as high initial investment, technological adaptation, and skill requirements remain, ongoing innovations and decreasing costs are making robotic solutions more accessible. In the long term, integrating robotics with AI, IoT, and data analytics will enable fully smart farming systems, ensuring food security and profitability in the face of climate change and a growing global population.

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INNOVATION OF SEED PELLETING

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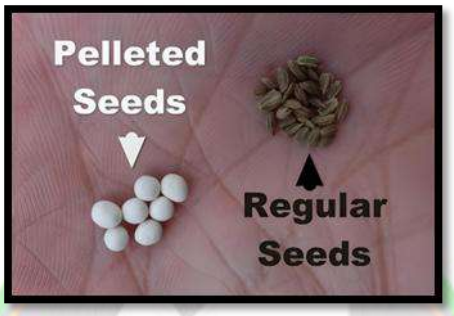
Abstract

In recent agriculture, seed pelleting is a game-changing method used to improve crop output, precision planting, and seed performance. In order to enhance seed protection, germination rates, and nutrient delivery, recent advancements in seed pelleting have concentrated on incorporating cutting-edge materials including biodegradable polymers, nanomaterials, and bioactive chemicals. These developments also encourage the use of controlled-release fertilizers and microbial inoculants, which promote sustainable farming methods. Additionally, the scalability and accuracy of the pelleting process have been enhanced by developments in automation and mechanization. This study examines the most recent advancements in seed pelleting technology, their uses in a range of crops, and how they might help with the world's problems with environmental sustainability and food security.

Key words: Seed pelleting, Precision agriculture, Seed coating technology and Germination enhancement

Introduction

The process of turning seeds into pellets is known as seed pelleting. This procedure creates a protective layer over the seeds. This makes it easier to plant seeds and increases the likelihood that they will germinate. It entails covering seeds with a blend of substances, usually consisting of a filler and an adhesive, in order to increase their size and uniformity. For further advantages, this procedure can also include bioactive bioactive substances, such as pesticides, fungicides, or plant growth regulators.



SCOPE OF SEED PELLETING

Improved Planting Efficiency:

1. **Precision Planting:**

Pelleting allows for more accurate and uniform seed placement, reducing the need for thinning and minimizing seed waste.

2. **Mechanized Sowing:**

Larger, uniformly sized pellets are easier to handle and feed through seeding equipment, making it ideal for large-scale automated planting.

3. **Reduced Seed Rate:**

By enabling precise sowing, pelleting can potentially reduce the amount of seed needed, leading to cost savings.

Seed Protection and Enhancement:

1. **Protection from Biotic and Abiotic Stress:**

Pelleting can protect seeds from pests, diseases, and environmental stresses like drought or waterlogging.

2. **Targeted Application of Treatments:**

Pellets can act as a carrier for beneficial substances like nutrients, biofertilizers, and plant protection products, delivering them directly to the seed and ensuring their effectiveness.

3. **Improved Germination:**

By providing a favorable microenvironment and delivering necessary nutrients, pelleting can enhance germination rates and seedling vigor.

Other Applications:

1. **Brand Identification:**

Pelleting can be used to add a distinctive color or marking to seeds for branding purposes.

2. **Species with Small or Irregular Seeds:**

Pelleting is particularly useful for small-seeded species that are difficult to handle and sow manually or with conventional machinery.

Materials Used:

Filler materials: Inert materials like clay, silicate powder, or other finely ground substances.

Adhesive materials: Substances that bind the filler material to the seed, often polymers or natural gums.

Active ingredients: Bioactive compounds like fungicides, insecticides, or growth regulators.

Benefits of Seed Pelleting:

Increased precision planting:

Pelleting facilitates the accurate placement of seeds, improving plant spacing and reducing the need for thinning.

Reduced seed rate:

By improving seed placement, pelleting can reduce the amount of seed required per unit area.

Enhanced seed protection:

Pelleting can shield seeds from pests, diseases, and environmental stresses.

Improved germination and emergence:

The coating can create a more favourable environment for germination and early seedling growth.

Reduced labour costs:

Easier handling and planting can reduce labour requirements.

Split Pellet Technology for Increased O_2 Availability

Slow and irregular germination linked to insufficient oxygen availability to the seed has historically been the main barrier to good seed pellet growth. Growers that plant lettuce in

saturated soil-water circumstances brought on by repeated irrigation after sowing can particularly benefit from the development of a splitting pellet such as our High-Density, Medium-Density, or Light-Density lettuce pellets. Oxygenated water can reach the seed directly thanks to a pellet that can split open when hydrated.

Advantages of Seed Pelleting:

Improved Handling:

Pelleted seeds are larger and more uniform in size and shape, making them easier to handle, especially for small seeds like carrots or those with irregular shapes.

Reduced Seed Waste:

Pelleting allows for precise planting of one seed per location, eliminating the need for thinning and reducing seed waste.

Enhanced Precision Planting:

The uniformity of pelleted seeds facilitates accurate placement in the soil, making them ideal for mechanized planting and reducing the risk of uneven spacing.

Faster Sowing Process:

The larger size and uniform shape of pelleted seeds can significantly speed up the sowing process, particularly when using automated sowing equipment.

Optimized Germination:

The coating on pelleted seeds can help regulate moisture uptake, potentially improving germination rates and seedling establishment, and some coatings may include beneficial additives like nutrients or protective agents.

Disadvantages of Seed Pelleting:

Higher Cost:

Pelleted seeds are generally more expensive than raw seeds due to the cost of the pelleting process and materials.

Shorter Shelf Life:

The coating on pelleted seeds can degrade over time, potentially reducing germination rates and viability, especially if stored improperly.

Limited Variety Availability:

Not all seed types are available in pelleted form, and some specialized or less common varieties may not be offered.

Potential for Reduced Germination in Specific Conditions:

Pelleted seeds may require careful watering and monitoring to ensure the coating breaks down properly and the seed is not suffocated, especially in wet conditions.

Organic Concerns:

Many pelleting materials are not organic, which can be a concern for gardeners seeking organic gardening practices.

Conclusion

Seed pelleting is a highly effective technique that enhances seed performance, precision planting, and overall crop establishment. By modifying the physical characteristics of seeds through the application of inert materials, pelleting facilitates easier handling, uniform sowing, and improved germination conditions. This method is especially beneficial for small, irregularly shaped, or lightweight seeds that are otherwise difficult to plant with mechanical seeders. In addition, seed pelleting can serve as a delivery system for fertilizers, pesticides, and biological agents, promoting early plant health and reducing input costs. As agriculture continues to modernize, seed pelleting stands out as a valuable tool for increasing efficiency, crop uniformity, and productivity.

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INDIAN SPINACH – AN UNDEREXPLOITED POTENTIAL VEGETABLE FOR NORTH INDIA

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Introduction

Indian Spinach is botanically known as *Basella alba* L. & *Basella rubra* L. having chromosome number of 2n= 48 and 2n = 44 respectively. This crop belongs to the family Basellacea. Fruits of Indian Spinach produces betacyanin; a purple red pigment used as a natural source of food colourant.

Malabar spinach, an excellent alternative to traditional spinach in hot weather, is a rapidly growing, edible vine with soft stems. Basella is not only an edible leafy vegetable but also a plant of ornamental importance in balcony and terrace. It is a warm-season soft succulent climbing, a sun-loving leafy vegetable valued for its succulent leaves with petioles. This crop has various names such as Indian spinach, Poi saag, Ceylon spinach, Surinam spinach, Chinese spinach, Malabar nightshade, and Vietnamese spinach. It is also called as a “flowing vegetable”. In South Asia, it is known by other common names, including vine spinach, red vine spinach, climbing spinach, creeping spinach, and buffalo spinach. Regional variations in nomenclature include “puishak” in Bengali, “poi ni bhaji” in Gujarati, “basalesoppu” in Kannada, “valchi bhaji” or “ovauchi bhaji” in Konkani, “vallicheera” in Malayalam, “mayalu” in Marathi, “poi saaga” in Oriya, “kodippasali” in Tamil, and “bachhali” in Telugu. Instead of its name, Malabar spinach, or *Basella alba*, is not botanically related to spinach. Malabar spinach differs from English spinach (*Spinacea oleracea*) in that it has glossy, broad, deep green leaves that are thick and mucilaginous, as well as a creeping vine structure. Its luscious, crisp, meaty leaves have a

distinct flavour profile with citrus overtones when eaten raw. However, it serves as a suitable substitute for spinach in various dishes and salads. Widely used in the tropics of India and Asia. Malabar spinach is known as "huangticai" in China, meaning Emperor's vegetable, emphasizing its historical and culinary significance.

Although the nutritional value of Malabar spinach is well known, standardised growing practices are not well established because the plant is mainly grown in kitchen gardens.

Origin and Distribution

Basella alba is native to the Indian subcontinent, New Guinea, as well as Southeast Asia. It has gradually gained naturalization in several places, including China, The West Indies, Fiji, Brazil, Colombia, tropical Africa, the Czech Republic, and French Polynesia. This is adaptable beyond its natural region, the plant has been used in traditional cuisines as far west as Japan and as far east as Africa. Furthermore, South America and the Caribbean have been introduced to Basella alba.

Description

Basella is a fast-growing vine (need support for growth) reaching about 8 to 10 meters in length with soft stems. Leaves are broad with mucilaginous texture. At present green and red-stemmed varieties are available. From axils of leaf small white or pink borne globular, fleshy elongated flower (in spikes) produced. From flowers, four parted purple to black coloured berries (fruits) formed. Under warm climate plants will produce mature fruits within 70 days of planting. Flowers are perfect white to pink in colour with persistent calyx, stamens have cordate anthers with short filaments and the ovary is monolocular. Both flowers and fruits are edible.

Cultivated varieties of Malabar spinach, characterized by their thick, green, semi succulent, heart-shaped leaves and mucilaginous texture, belong to dicotyledonary perennial vines. Depending on the species, the flowers can have a variety of colours, including white or white-pink.

After fertilization, these flowers become tiny, incredibly ornamental, purple berries with a solitary seed. Basella rubra has heart or oval shaped leaves with a thick, meaty, and mucilaginous texture. The leaves have a mild flavour. These stalked leaves have a length ranging from 5 to 12 cm, and they taper to a pointy tip with a cordate base. There is an additional layer of colour contrast in the leaves due to the presence of red veining. The axillary spikes are solitary, ranging in length from 5 to 29 cm.

Basella rubra is characterized by pink or purplish stems and veins running through the leaves. In contrast, Basella alba has green stems, while Basella rubra features reddish-purple stems.

Health benefits and uses

- Used to treat tooth ache by tribals
- Red pigment isolated from fruits has anti-inflammatory and potent anti-oxidant activity,used in wound healing, anti-microbial activities, anti-viral activity, insecticidal property, anti -ulcer activity, etc.
- Young stems and leaves of basella are more palatable they can be eaten as raw or cooked as other greens.
- By mixing leaves of this plant with flour of gram and frying deep them in mustard oil used to make pakoras (best for regular evening nutritive snacks).
- Regular consumption of basella slows down the aging process.
- In Ayurveda, basella is used to treat anaemia, dysentery, cough, and cold-related infections.
- It is more valued for high population countries like India because it checks malnutrition of the children.
- Mucilaginous leaves have gastroprotective, antioxidant, anti-inflammatory, ulcer healing, and wound healing properties.
- In males the consumption of basella increases the testosterone levels, thus boosting the libido and regular intake restores the vitamin A deficiency in men.
- The decoction which is made from leaves acts as the safest laxative in children and pregnant women.
- Consumption of paste of red basella roots in combination with rice-washed water for 30 days in the morning with an empty stomach can cure irregular periods.
- From the fruit of basella dark purplish violet colour food colorant was prepared.
- Leaves and roots of basella are used for reducing the afterbirth pain and stomach pains and enhance milk production, Leaves are used for preventing constipation and gonorrhea.
- Their mucilaginous properties make them an effective thickening agent in soups and stews.

- Caution is advised during cooking, as overcooking can result in sliminess.
- The consistent fiber content in the stem and leaves, when paired with mucilage, facilitates easy digestion, lowers the absorption of cholesterol, and helps avoid constipation.
- In addition to supporting a healthy cardiovascular system and lowering the incidence of heart attacks and strokes, consumption protects lung and oral cavity cancers.
- Malabar spinach contains a high amount of vitamin C, which is a potent antioxidant that aids in scavenging dangerous free radicals and promotes the development of resistance against infectious diseases.

Composition

Indian spinach, a common leafy vegetable, boasts a rich nutritional profile, encompassing substantial amounts of carbohydrates, starch, iron, calcium, potassium, magnesium, vitamin A, carotene, thiamine, riboflavin, ascorbic acid, and vitamin E. Similar to other dark green leafy vegetables like spinach, Malabar spinach is a source of lutein and zeaxanthin, both valuable carotenoids. Despite being low in calories, it stands out for its high protein content per calorie. The juicy mucilage it contains is notably abundant in soluble fibre (2.37%). Esteemed in various East Asian cultures for its wholesome phytonutrient content, Malabar spinach is recognized for housing specific phenolic phytochemicals that function as antioxidants. Its robust and succulent leaves are a noteworthy source of non-starchy polysaccharides, particularly mucilage.

Nutrition: Nutrient content per 100g of edible portion

Particular	**Quantity**	**Particular**	**Quantity**
Moisture	92.8- 93 %	Carbohydrates	0.4 g
Energy	31 kcal	Fat	1.9 g
Fibre	0.3 g	Ascorbic Acid	74 mg
Vitamin A	3250 IU	Thiamine	84 mg
Riboflavin	126 mg	Carotene	32.42 mg/100 g DW
Iron	5.45 mg	Total Carotenoid	121.56 mg/100 g DW
Calcium	187 mg	Oxalic Acid	60-84 mg
Phosphorus	83.5 mg	Magnesium	103 mg

Betalain content of 80 mg/100 g in fresh leaves and 200 mg/100 g in fresh fruits are also found in the crop.

Soil and climate

Sandy loamy soils, rich in organic matter with a pH ranging from 5-8 are highly suitable for its cultivation. Soil should be well drained and aerated.

It requires a hot and humid climate. The plants are sensitive to frost. Low temperatures restrict plant growth and reduce yields. Flowering occurs during short-day months of the year. For cultivation of Malabar spinach; tropical and subtropical climate are suitable. Under temperate climates, it grows as annual. This crop demonstrates remarkable tolerance to high temperatures, making it a resilient choice for cultivation during hot weather when many other crops struggle.

Cultivated Varieties

Malabar spinach is distinguished by two botanical varieties:

(i) ***Basella alba***, characterized by green stems and deep-green leaves, and

(ii) ***Basella rubra***, featuring purplish stems and deep-green leaves adorned with pink veins.

The green-leaved varieties are particularly popular in Uttar Pradesh and Punjab, while both green- and red-leaved varieties are prevalent in West Bengal, Assam, and the states of South India.

IIVR, Varanasi has released three varieties viz. Kashi Poi-1, Kashi Poi-2 & Kashi Poi-3. Kashi Poi-1 & Kashi Poi-3 are pole types while Kashi Poi-2 is bushy type and is suitable for high density planting of the crop.

Propagation

The stems of basella can form roots rapidly whenever they touch the soil hence it is easily propagated through stem cuttings, root cuttings and seeds. Although, Basella is propagated through seeds but poor germination is noticed because of the hard seed coat. For fast germination of seeds mechanical scarification and soaking them overnight in water before planting is beneficial. A minimum temperature of 18–21°C is necessary for seed germination. It takes 10 to 21 days at a temperature of around 20°C to germinate.

Sowing Time: March to April is appropriate time for sowing in North India.

Seed Rate: 12- 16 kg seeds are required foe sowing in one hectare.

For direct-seeded crops: Row to row spacing should be kept 45 cm while plant to plant also 45 cm, with the depth of sowing at 1.5–2.5 cm.

Thick cuttings, around 20 cm long, are generally the best for quick growth and simple replication

Manures and Fertilizer: 40 tonnes/ha FYM and Nitrogen at a rate of 60–80 kg, phosphorus at 60 kg, and potash at 40 kg per hectare before sowing are recommended as basal dose. After each cutting application of 20 kg/ha nitrogen increase the leaf yield.

Irrigation: For optimal growth and to prevent flowering and bitterness in leaves, Malabar spinach necessitates consistent moisture. The irrigation frequency should be adjusted based on the soil type and prevailing weather conditions to maintain soil moisture for better development. Thin, wiry stems and little leaves might result from lack of moisture. During the rainy season, irrigation needs are influenced by the frequency and intensity of rainfall. Irrigation For optimal growth and to prevent flowering and bitterness in leaves, Malabar spinach necessitates consistent moisture. The irrigation frequency should be adjusted based on the soil type and prevailing weather conditions to maintain soil moisture for better development. During the rainy season, irrigation needs are influenced by the frequency and intensity of rainfall.

Intercultural Operation:

Hoeing and weeding: In the early stages of Malabar spinach crop growth, it is essential to keep the field free from weeds. Since the seeds of Malabar spinach take more time to germinate, and the plants may not recover easily from weed infestation, regular hoeing and weeding are crucial to maintain a weed-free environment. One or two rounds of hoeing and weeding are essential to effectively suppress weeds in the Malabar spinach field. Hoeing serves a dual purpose by not only removing unwanted weeds but also enhancing soil aeration. Improved aeration benefits the roots, promoting better growth and overall plant health.

Training: Malabar spinach, being a rapidly growing vine crop, achieves its best production when provided with trellises. In the absence of early-stage harvest for consumption, staking becomes necessary. The plant requires a trellis or alternative support structure for twining its vines. To maintain an upright position for the plants, the vines can be trained on a bower system or poles, facilitating the clipping of tender shoots while leaving a few leaves for continued growth and multiple harvests. In instances where providing support is not feasible, the plants can be allowed to crawl on the ground. Typically, under normal conditions, Malabar spinach displays

an appealing growth pattern, quickly climbing trellises and other supporting structures throughout most of the warm season.

Mulching: Applying organic mulch is recommended after transplanting, specifically when the seedlings reach a height of 10 to 15 cm. This practice helps in conserving soil moisture over an extended period, which is crucial for promoting rapid growth and achieving a higher yield.

Harvesting and yield: Basella reaches maturity 50-60 days after seed sowing. Harvesting is done by trimming leaves and tender stems of 15-25cm long with a knife subsequent harvest can be done for every 3-5 days. The yield varies from 140-185 q/ha. In late flowering type the yield of around 300q/ha is possible. For bushy maintenance of plant in backyards aggressive pruning is needed which do not cause any harm to plants. Plucking of leaves encourages more growth. Until the plant produces new shoots actively, we can continue plucking leaves and tender stems. The yield of fresh leaves per plant is 1-2kg.

Leaf spot, leaf blight, damping off, anthracnose, charcoal rot, Basella Rugose Mosaic Virus are major diseases of the crop.

No major insect is reported so far except for few reports for attack of caterpillars.

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INTEGRATED FARMING SYSTEM WITH SHEEP AND GOAT

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Introduction

The farmers are currently focused primarily on crop production, which exposes them to a high level of income and employment uncertainty. It is essential to develop the right strategy for increasing a farm's revenue in this competition. In the agricultural economy, the integration of diverse agricultural businesses, such as farming, animal husbandry, fisheries, forestry, etc., has tremendous possibilities. These businesses not only augment the farmers' income but also boost the use of family labour. The integrated farming system strategy promotes a shift in farming methods in order to optimize production in the cropping pattern and ensure the best possible use of resources. The integrated system makes better use of farm wastes for productive purposes. Farming would be prosperous with a sensible combination of agricultural businesses like dairy, poultry, piggery, fishery, sericulture, etc., that are appropriate for the farmers' socioeconomic position and the local agro-climatic circumstances.

Benefits of an Integrated Farming System:

- Increased food production to meet the demands of our nation's rapidly growing population
- Higher farm income from effective residue recycling and related elements
- The integration of related activities will make healthy food available that is high in protein, carbs, fat, minerals, and vitamins.

- By planting fodder crops as intercropping and border cropping, enough nutritious food will be produced for animal components such as dairy cows, goats and sheep, pigs, and rabbits.

Integrated Farming System with sheep and goats:

In the past few years, the steady income from agricultural crops has grown erratic. Integrating crops with agro-based industries like livestock farming is critical in order to remedy these. Today's growing demand for meat in urban and rural areas may allow small and part-time farmers to make a decent profit by trading with the goat and sheep farming sector. Since a shed requires less upkeep and investment, it can be constructed in conjunction with agricultural crops.

An integrated farming system's advantages

- Enhanced productivity
- Net profit increase and set income
- Environmentally friendly expansion in agriculture
- A well-balanced diet
- Atmosphere devoid of pollution
- Recycling of agricultural waste
- Increase in job opportunities
- A high standard of living

Raising goats in dryland IFS:

By doing this, integrated farmingwhich is ideal for dryland of one hectare with crop cultivation and goat rearing (20 females: 1 male)triples production. Twenty sheep may produce 45 lambs annually. Additionally, sheep manure produces 200 kg of N, 106 kg of P, and 91 kg of K, as well as an extra income of 40 to 50 thousand rupees. Therefore, sheep will receive the necessary nutrient-rich fodder from groundnut leaves, red gram bran, black gram bran, and tree leaves like Agathi, Barnyard, neem, Tamarind, Supapul, Desmanthus, Portia, and surrogates like tree leaves Acacia, Kutaivelan, Velikattan, and Raintree pods. It reduces the need for animal feed, and more meat production results in more revenue. The pasture provides sheep with an adequate amount of green grass during the rainy season. Consequently, six to eight hours of grazing each day is sufficient for sheep. Green grass is not available throughout the summer (March through August). As a result, in the Cause of mixed ration (Concentrate) giving to

sheep's is necessary. Integrated farming is appropriate for sheep farming in wetlands: Up to 30–35 sheep may be raised on a single acre of land. The fodder plants of cumbu Napier CO-4 (40 cents), Hedge lucerne - (30 cents), and fodder sorghum CO.F.S. 29 - (30 cents) can guarantee a year-round supply of fodder. In this CO 4, grass is a high-yielding forage plant. Sheep are drawn to it by its high tillering potential, thin stalks with lots of leaves, ease of palatability, and lack of thorns. In dryland pastures, these grasses grown with legume fodder, such as Stylo, in a 3:1 ratio, would boost goat productivity. The sheep are given little bits of the forages that have been produced. Typically, a sheep gives birth to three lambs every two years. This will be more lucrative than any other livestock. In addition, around 2 to 3 kg of green fodder should be given to goats each day.

Goat rearing and agroforestry:

Raising livestock alongside agriculture is more profitable than focusing solely on agriculture. In addition to raising goats in agriculture, producers who raise 20 to 30 goats annually will also earn at least 40 to 50 thousand rupees in additional profit. Integrating agroforestry with goat production has the potential to bring several advantages to farmers. The second flock of Jamnapari ,Only dry and fallow ground may be used for this undertaking. The amount of water required by this method is quite little. The kennel approach and agroforestry for raising goats.The cultivation of kollukattai grass for 25 cents and the new forage variety hedge lucerne for 25 cents are both recommended. An acre based on a water facility that provides at least 25 cents of fodder maize CO.F.S.29, 5 cents of land used to erect fences, and a kennel method shed in the middle. The remaining area could have Soundal, Agathi, and Gliricidia trees planted along the boundary. The raising of forage crops and maintenance of readiness occurs three to four months before purchasing goats. Raising goats using the kennel approach Building the Shed One goat needs between 10 and 15 square feet. Tile set or coconut palm leaf over the shed .The barn's one side is covered with aluminum plates to feed and retain it. Automated

device for water delivery .The cage should be placed approximately three feet above the ground. 200 grams of mixed forages daily for pregnant ewes, 100 grams for mature ones, and 50 grams for younger ones. Demands between 1 and 3 liters of water each day for goats. It also ate 250–300 grams of tree leaves and 1–2 kg of forage sorghum daily.

Integrated sheep farming:

Sheep farming in dry areas using an integrated farming method is a lucrative industry. The sheep are fed crops grown in these areas together with fodder trees. It is high in minerals and proteins. Among the important ones are Agathi, neemSupapaul, Acacia sp, kalyanamurungai, Gliricidia, and Raintree. Compared to other forages, tree leaves have more nutrients. Mixing tree fodder with cereal or legume fodder, rather than just giving tree fodder, can lower the cost of feeding fodder sorghum and raise sheep output. Giving maravakaittivanankalait alone, or mixed with cereal grains or forages pulvakait, can boost output. Goats typically give birth to their young at any time of the year, and they also begin lactating between 60 and 90 days following delivery. Tamil Nadu is divided into three oestrus periods. March to April from July through August from September until October During March and April, goats enter their estrus cycle, and they give birth to lambs between July and August. Because the southwest monsoon began at the beginning of June, both sheep and lambs had adequate food.

The sheep's ability to produce milk was excellent, which boosted the lamb's growth. Those sheep give birth to lambs in November and December throughout July and August. The development and well-being of lambs in some regions are brought about by harsh winters and snowfalls. In the same way, fodder shortages are likely in locations where rainfall is essential. When the young ones are separated from their mothers and not given enough food, they will begin to grow. The rise in offspring mortality. Maintaining milk production might help remedy the rainfed crops harvested in December and January that can be used as feed for the mother sheep to boost milk output. If they do get to keep the mother sheep, the byproducts of agricultural products can be corrected by maintaining milk production.

Strategies for Enhancing Fodder Production:

- To boost productivity, legume feed can be intercropped with other plants.
- Forage crops for agroforestry and social forestry systems can be produced. For instance, a ratio of 3:1 can be used to cultivate stylo between trees and supapaulkolukattai grass.
- Fruit tree mango, sapota, guava, lemon, coconut, and tamarind intercrop forages are planted in between the trees on farmland.
- Grow excellent grass pastures in bad soil. Plant legumes like Stylo and ciratro, as well as kolukattai grass and marvel grass.
- For this reason, the future of agriculture relies on the organized farming of marginal and small farmers. If the integrated farming method is followed, farm owners may raise their level of living and income depending on their available resources .

Conclusion

The integration of the sheep and goat metaphor into Internal Family Systems (IFS) therapy offers a rich symbolic lens through which to explore the internal dynamics of the human psyche. In IFS, every partno matter how protective, skeptical, vulnerable, or rebellioushas a positive intention and seeks harmony within the system. By framing some parts as "sheep" (gentle, protective, compliant) and others as "goats" (independent, skeptical, reactive), therapists and clients can gain deeper insight into internal polarization.

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IMPORTANT POTATO DISEASES THREATEN TO HIGHER PRODUCTION AND THEIR MANAGEMENT

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Introduction

Potato (*Solanum tuberosum L.*) belonging to family Solanaceae is a native of South America where it has been under cultivation for over 6,000 years. It is one of the most important crops of the world, ranking next only to rice, wheat and maize. The major potato growing countries in the world are China, India, Russia, USA, Ukraine, Poland, Germany, Belarus, Netherlands, France, UK, Canada, Turkey and Romania. Potato was introduced into India in early 17th century by Portuguese. It has higher nutritive value and rich in carbohydrates, proteins, minerals and vitamins. It is also a rich source of potassium and therefore, very good for patients suffering from heart ailments. India is second largest producer of potato with a production of 56.17 million tonnes from 2.2 million ha during 2020-21 with an average productivity of 25.1 tonnes per hectare. Potato is one of the most popular crops grown in almost all the states. The major potato producing states are Uttar Pradesh (33.46 %), West Bengal (24.12 %) and Bihar (15.09%) Gujarat, Madhya Pradesh, Punjab, Assam, Haryana, Jharkhand and Chhattisgarh. The average productivity of 25.1 tonnes per hectare much below the present highest productivity of the world. Among the several yield limiting factors, diseases are major constraints to fetch higher production of this crop. The major diseases of the potato and their management are as follows:

Late blight

Causal organism: *Phytophthora infestans*

Symptoms: It is most destructive diseases of potato crop.

The disease appears at any time of the plant growth. The symptoms appeared as water-soaked, faded green lesions on foliage. Lesions enlarge rapidly and become necrotic, and turn brown when dry or purplish black when wet. The necrotic areas appear at the tip or margin of the leaves and spread downward or inward. The lesions may coalesce and killing the entire leaf within a few days in moist weather and the pathogen may spread to petioles and stems, killing the entire plant, the decaying plant material give off a foul odour. Lesions on stems and petioles are black or brown. Stem lesions are brittle and stems frequently break at the point of the lesion. Tuber infections are characterized by irregular, slightly depresses areas that are variable in size.

Disease cycle: The pathogen survives as dormant mycelium in the tubers left in the field. In other areas the persisting mycelium in seed tubers stored at low temperature is the primary source of infection. Under cool, moist conditions, the fungus can sporulate on the foliage of the plants. The numerous conidia produced on the host foliage spread by wind and irrigation water and cause secondary infections, sometimes resulting in epiphytotic outbreaks of the disease and infections will occur throughout the growing season. Later on, with the advancement of the disease, the sexual stage is formed resulting in the oospores, which can survive adverse climatic conditions. When the fungus is present in soil it attacks the tubers and hibernates therein.

Management:

- Field sanitation and Use high-quality disease-free seed.
- Grow resistant cultivars like Kufri chipsona, Kufri Anand, Kufri Badshah, Kufri Kanchan, Kufri Kishan, Kufri Sindhuri and Kufri Kuber etc.
- Use balance fertilizer and Stop irrigation after seeing the disease.
- Spraying of mancozeb or propineb or chlorothalonil @ 2 kg/ ha prior to disease infection.
- Spraying of Cymoxinil +Dithane-M 45 @ 2 kg/ ha or Fenomidon +Dithane-M 45 @ 2.5 kg/ ha or Dithane-M 45 @ 2 kg/ha + Dimethomorph@ 1 kg/ha in 1000 lt of water is recommended.
- Proper aeration should be maintained in cold storage.

Early blight

Causal organism: *Alternaria solani*

Symptoms: It is worldwide in distribution and is one of the most important foliage diseases in areas under favourable weather conditions. The disease appears as small, isolated, irregular, scattered, pale brown to dark brown spots on lower leaves of the plants which progress upwards. These spots are often covered with a deep greenish blue growth of the fungus. The necrotic spots are mark internally by a series of concentric rings form on leaves and to a lesser extent on stems, which produced a target board effect. The rings are more prominent in large blotchy spots and give them a target board effect. The disease can be distinguished from late blight by the absence of white cottony fungal growth. When a spot appears on the vein, a part of it gets necrosed.

Disease cycle: The fungus overwinters on plant debris and infected tubers in soil and serve as primary infection to the next crop. The disease usually occurs along fields adjacent to potato fields from the previous season. Tubers contaminated with conidia and mycelium is another source of primary infection. Secondary infection takes place by the means of conidia produced on the primary lesions. These are dispersed to other plants by wind, rain, irrigation water, or mechanical means throughout the growing season. Tuber infection occurs during harvesting and is most severe when the tubers are bruised or wounded. Collateral hosts such as tomato may also play a significant role in the perpetuation and dissemination of the fungus.

Management:

- Follow 2-3 years crop rotation and field sanitation
- Remove infected plant debrisfrom the field and destroy
- Grow resistant varieties
- Spray protectant fungicides Mancozeb (0.2%) or Blitox 50 (0.25%) at the first sight of early blight symptoms to control the disease.

Stem canker and black scurf

Causal organism: *Rhizoctonia solani*

Symptoms: There are two distinct phase of the disease, (i) Stem canker phase and (ii) Black scurf phase. In stem canker phase, when seed tuber sprout the

growing tip shows delayed emergence or failure to emerge. Sprout tips when germinated may turn brown and die. A dormant bud near the base then sprouts which also kill but in normal condition it may grow. Slightly sunken brown cankers of variable size and shape affect stolons and stems at or below the soil which resulted yellowish or purplish leaves that curl upwards. This causes irregular stands of weak, spindly-looking plants which affects the yield of tubers. In Black scurf phase hard, dark brown or black sclerotia of irregular size and shape form on the tuber surface. These sclerotia are normally skin deep. The sclerotia vary from netted or scurfy residues to individual black masses on the tuber surface. Tubers may be misshapen, cracked, or may develop a russet like skin.

Disease cycle: The fungus causing stem canker and black scurf is present in nearly all soils, in plant debris, and as sclerotia. It grows over a wide range of temperatures. The fungus survives in soil with decomposing plant residue. Sclerotia can survive on infected tubers and persist in the soil for many years. Sclerotia germinate and invade stems or sprouts. Roots and stolons are invaded as they develop throughout the growing season. Sclerotia can form on new tubers at any time, but maximum development occurs when tubers left in the soil after the death of the plant.

Management:

- Use clean and disease-free seed.
- Crop rotation
- Seed treatment with 3% boric acid before sowing
- Seed treatment befor sowing eith pencycuran or azoxistrobin or thiafluzamide reduce the black scurf disease.
- Use biological control agents like Trichoderma to reduce soil inoculum.

Fusarium wilt

Causal organism: *Fusarium* spp.

Symptoms: There are several species of *Fusarium* associated with the wilting of potato. Among them *Fusarium solani* f. sp. *radicicola* is associated with dry rot while *Fusarium solani* f. sp. *eumartii* is associated with wet rot, besides these *Fusarium oxysporum* f. sp. *tuberosa* also causes wilt in potato crops. The main symptoms of the wilt is yellowing of the foliage, brown discolouration of the vascular system and wilting of the leaves and stems. In the *oxysporum* type of wilt the wilting occurs by cortical decay of the underground part of the stem. The leaves suddenly become yellow followed by rapid wilting of plants in irrigated crops while in non-

irrigated crops the disease develops slowly from root invasion. Browning of vascular bundles is more pronounced in this case. In *eumartii* type of wilt, leaves become yellow followed by small brown spots in the interveinal areas of the youngest leaves. Vascular discolouration occurs throughout the root system and also in the tubers. In the tubers there is internal browning of the vascular ring, when cut and pressed does not yield any ooze but if kept in moist chambers shows growth of the fungus on the ring. Stem-end browning of new tubers may also occur.

Disease cycle: Wilting is favoured by hot dry weather. High temperature and wounds on the tubers help in development of dry rot. The fungi causing wilt and tuber rots are soil-borne as well as tuber-borne. Infected tubers and soil adhering the tubers can carry the pathogen to long distances. Infection from soil-borne inoculums occurs through root tips or through wounds. Spread of the pathogens in the crops is mainly through irrigation water.

Management:

- Protect tubers to minimize bruising and mechanical injuries during handling and transportation.
- Tubers should be stored for a short period in humid air to promote rapid corking on injuries. Storage temperature of 5^0 – 13^0C (41^0 – 155^0F) reduce spread of tuber rot.
- Crop rotation and field sanitation.
- Grow disease free clean seed and seed treatment before sowing.

Verticillium wilt

Causal Organism: *Verticillium albo-atrum, V. dahliae*

Symptoms: The disease is characterized by leaf yellowing, which begins at the plant base and may develop unilaterally, restricted to the sides of leaves and the stem later on the plant may wilt. The vascular system of the lower stem turns brown. Plants frequently become yellowed and mature early without pronounced wilting. Stems wilted by *V. albo-atrum* are blackened by the presence of a blackish resting mycelium. However, when *V. dahliae* causes wilting, the lower portion of the stem becomes greyish because of the presence of microsclerotia.The vascular ring of tubers may

have light brown discoloration extending from the stolon end up to more than halfway through the tuber. Tubers often have light tan and discoloured eyes.

Disease Cycle: These fungi are long-lived in soil or plant debris and have a wide host range, including other solanaceous plants, cotton, and weeds. Surface-borne inoculum on seed tubers is important in disease spread. Interaction with nematodes (*Meloidogyne, Pratylenchus, Globodera*), fungi (*Rhizoctonia, Colletotrichum, Fusarium*), and bacteria (*Erwinia*) increases damage.

Management:

- Use crop rotations
- Plant disease resistant varieties
- Seed treatment before sowing
- Irrigate the crop frequently to prevent water stress.

Bacterial Brown Rot and Wilt Disease

Causal Organism: *Pseudomonas solanacearum*

Symptoms: Bacterial wilt or brown rot is the most serious bacterial disease of the potato in the tropical, subtropical and warm temperate regions of the world. The characteristic symptoms of the disease are stunting, yellowing and wilting of the plants which finally collapse. Initial wilting may affect one side of a leaf first. Later symptoms are severe wilt and browning and desiccation of leaves, followed by death of the plants. The vascular bundles also show browning which is often visible from the surface of the stems of infected plants in the form of dark patches. The skin of infected tuber shows discolouration. When a cross section is made of infected tuber a grayish white slime exudes may ooze through vascular rings. This is also known as *bangdi* or *bangle* disease due to formation of brown rings in the tubers.

Disease Cycle: The pathogen can survive through soil, seed tubers and cultivated solonaceous host. Soil and infected tubers serve as primary source of inoculums. Spread also occurs by water flowing along rows and from field to field. Latent tuber infection occurs when infected seed is planted in cool locations or in tubers infected late in the growing season. Wilt develops rapidly at high temperatures.

Management:

- ❖ Crop rotation is most effective
- ❖ Seed tubers should be obtained from disease free fields.

- Summer ploughing
- Destroy the disease plant debris
- Treat the tuber with streptocycline before sowing

Black leg and soft rot

Causal organism: *Erwinia carotovora*

Symptoms: Blackleg of potato plants and soft rot of tubers are widely distributed disease of humid climates caused by the bacteria. Blackleg can occur at any stage of development when moisture is excessive. The typical black leg symptoms in the field are characterized by a striking brown black or jet black colour of the stem near the ground level. The discolouration usually starts from the seed tubers. The infected plants are commonly stunted, erect and chlorotic. Instead of spreading normally, the branches and leaves show a tendency to grow upward. Yellowing and upward rolling of leaflets may occur, often followed by wilting and death of the plants.

In soft rot of tubers the tubers are transformed partially or wholly in to a soft decayed pulpy mass in moist and high temperature. In wet weather, the decay on the stems is soft and slimy, but under dry conditions, infected tissues may become dry and shriveled. Tubers produced by infected plants may have symptoms ranging from slight vascular discoloration at the stolon end to soft rot of the entire tuber. Tubers with soft rot have brown, slightly sunken, water-soaked areas on the surface. Advanced disease symptoms include slimy, completely rotted tissues with a foul odour.

Disease cycle: The seed tubers serve as primary source of inoculum for blackleg in the field. Bacteria can be spread during seed cutting and handling. After being planted, the seed pieces decay, releasing bacteria into the soil and sometimes infecting the stem of the host plant. The primary inoculum for soft rot of tubers comes from decaying seed pieces, infected plants, infested soil, and contaminated seed cutting, or harvesting equipment. Infection occurs through lenticels or wounds.

Management:

- Avoid planting in wet soils and do not over irrigate.
- Avoid planting when soil temperature is below 55°F.
- Use high-quality disease-free seed
- Plant tubers in well-drained soil.

- ❖ Remove infected plants as soon as they appear.
- ❖ Harvest tubers when ripe, handle them gently, and do not leave them exposed to sun.
- ❖ Tubers must be dry prior to storage or transportation.

Common scab

Causal organism: *Streptomyces scabies*

Symptom: It is a common disease in most of the potato-growing areas, which affects only quality, not yield of the crop. Two types of symptoms are produced on the tubers (i) shall ow or superficial or reticular and (ii) deep or pitted. In shallow symptoms the affected tubers show superficial corklike lesions (russet scab) raised above but often sunken slightly below the tuber skin. The lesions typically are circular, vary in size, and tan to brown in color, with corky areas that develop randomly across the tuber. Lesions may become irregular in shape when they coalesce. In deep pitted scab the lesions are 1-3 mm or more in depth and are darker than shallow lesions. These pitted scab lesions are dark brown to black, and the tissues underneath are often straw-colored and translucent. More than one type of symptom may be present on a single tuber.

Disease cycle: The pathogen is introduced into the soil through infected tubers and persists indefinitely once the soil is contaminated. The pathogen can also survive on decaying plant debris and is spread by wind, water or by infested soil or equipment. As soon as tuberization begins, the newly formed tubers are susceptible. They become infected through the stomata or lenticels. Infected tubers may play the main role of its distribution on large area. Mature tubers with a well-developed periderm are no longer susceptible to infection.

Management:

- ❖ Crop Rotation
- ❖ Green manuring before planting may reduce the incidence of common scab
- ❖ Use disease free seeds for planting and seed treatment before sowing
- ❖ Maintain high soil water levels during tuber set and enlargement.
- ❖ Maintain soil pH levels at 5 to 5.2 with acid-forming fertilizers or sulphur.
- ❖ Use biological control agents like Trichoderma to reduce soil inoculum.

Potato Leaf roll Virus:

Causal Organism: PLRV (Luteovirus)

Symptoms: Potato leaf roll virus is the most important potato virus and is common in all potato growing areas. Yield losses in highly susceptible cultivars can reach 90%. The name "leaf roll" is partly descriptive of the symptoms on foliage of infected plants but the most characteristic symptoms develop in tuber tissues. Primary symptoms are rolling of upper leaves, along the margins, leaving the midrib at the bottom of a trough. This rolling of leaves starts from the lower leaflets and progresses upward throughout the plant. Tubers of highly sensitive cultivars develop net necrosis in the flesh. Secondary symptoms (of plants grown from infected tubers of subspecies tuberosum) are rolling of basal leaves, stunting, upright growth, and paleness of upper leaves. Rolled leaves are stiff and leathery, and sometimes tinged purple on their undersides. PLRV is transmitted in a persistent manner by several aphid species among them most important is *Myzas persicae*. In addition to infecting potato, the virus infects other solanaceous crops and weeds (tomato, tobacco, jimsonweed, etc

Management:

- It can be managed by selecting healthy plants and eliminating diseased plants through roguing.
- Systemic insecticides will decrease spread by aphids.
- PLRV is the only potato virus known to be eliminated from tubers by heat treatment.
- Use resistant varieties.

Mosaics Disease

Causal Organism: PVX, PVS, PVM, PVY and PVA

Symptoms: Symptoms of mosaic disease in potato varies with the varieties and virus strains which include dwarfing, mottling and necrosis. These viruses cause five types of mosaic symptoms (i) mild mosaic, (ii) Super mild mosaic (iii) severe mosaic (iv) Rugose mosaic (v) crinckle.

Potato Virus X (PVX) is one of the most widely distributed viruses of potatoes because no symptoms develop in some varieties (latent mosaic), the full extent of damage with PVX is not recognized which is mild type of mosaic in the plants. PVX may cause yield losses above 10%, with the extent varying according to strain and potato cultivar. It is transmitted through infected tubers and by contact. Infection may be mild in some cultivars and is frequently latent. Virulent strains may cause crinkling.

Potato Virus S (PVS) is common and may cause mild symptoms. It has little effect on yield. It is transmitted through infected tubers, by contact, and by aphids in some strains. Infection is normally latent although some cultivars react with mild mosaic or faint vein banding. A few sensitive cultivars react with severe bronzing, necrotic spotting, or even leaf drop.

Potato virus Y (PVY) is one of the most important viruses infecting potatoes. It is readily spread by aphids in a nonpersistent manner as well as mechanically by human activity and may result in severely affected the crop yields. PVY is seed borne and can interact with other viruses such as PVX and PVA to result in heavier losses. Symptoms caused by PVY infection can vary depending upon the strain and potato variety grown. Use disease free clean seeds.

- Roguing is useful only when obvious symptoms develop.
- Detop of the foliage in the 3rd or 4th week of December.
- Spray of systemic insecticdes to control virus vector

Black heart or Hollow heart

Causal Organism: Physiological disorder

Symptoms: The black heart of potato is a non parasitic disease commonly found in storage. This is due to high storage temperature and low oxygen supply. Sometimes it may occur both in the field and in storage. High soil temperatures and waterlogged soils contribute to black heart development in the field. Disease is characterized by a bluish-black to black discoloration of internal tuber tissues. The discoloration occurs in an irregular pattern, usually with a distinct line between healthy and affected tissue. A cavity is also form in the affected area which is surrounded by discoloured tissue and is referred to as "cat's eye." The affected area usually remains firm and odourless. If the affected tubers are cut to examine the cut surface turns pink, then dark brown to black.

Management: Provide potatoes in transit and storage with good ventilation and maintain at the proper temperature.

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A NOVEL APPROACH ON EFFECT OF OZONE LAYERS IN SEED GERMINATION

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Abstract

The need for food inevitably rises as the world's population grows. Rapid urbanization and industrialization have also resulted in a significant reduction of agricultural land, which has a negative impact on producers' access to land. Nonetheless, by increasing crop productivity, enhancing seed germination could ensure the food safety of the general public. The conventional chemical techniques for enhancing seed germination have several drawbacks, such as being labour-intensive, time-consuming, and harmful to the environment. The effects of ozone spraying on seed germination and plant growth have recently gained more attention. A number of possible uses for this method in the food sector have begun to surface.

Key words: Ozone layer, seed dormancy, seed germination and seed viability

Introduction

In addition to being a potent antibacterial, ozone also promotes germination. Depending on the concentration and duration of exposure, ozone can affect seed germination in both favorable and negative ways. In general, low ozone concentrations can improve seedling vigor

and germination rates. Higher concentrations, however, may be harmful. Ozone can promote the biochemical processes involved in germination and act as a disinfectant, possibly dispelling seed dormancy. On the other hand, too much ozone exposure might harm seed germination and viability.

POSITIVE EFFECTS:

Breaking Dormancy:

Ozone can help break dormancy in some seeds, allowing them to germinate more readily**.**

Enhanced Germination:

Low concentrations of ozone can stimulate the production of hormones like jasmonic acid, which promotes root growth and germination.

Improved Seedling Vigour:

Ozone treatment can lead to healthier and more vigorous seedlings.

Increased Tolerance:

Ozone exposure may increase the plant's tolerance to various environmental stresses.

NEGATIVE EFFECTS:

Germination Inhibition:

High concentrations of ozone can inhibit germination and even cause seed mortality.

Delayed Germination:

In some cases, ozone exposure can delay the initial germination time.

Reduced Germination Percentage:

Excessive ozone can lead to a decrease in the overall percentage of seeds that successfully germinate.

Metabolic Disruption:

While ozone can stimulate certain biochemical processes, excessive exposure can disrupt the normal metabolic pathways involved in germination.

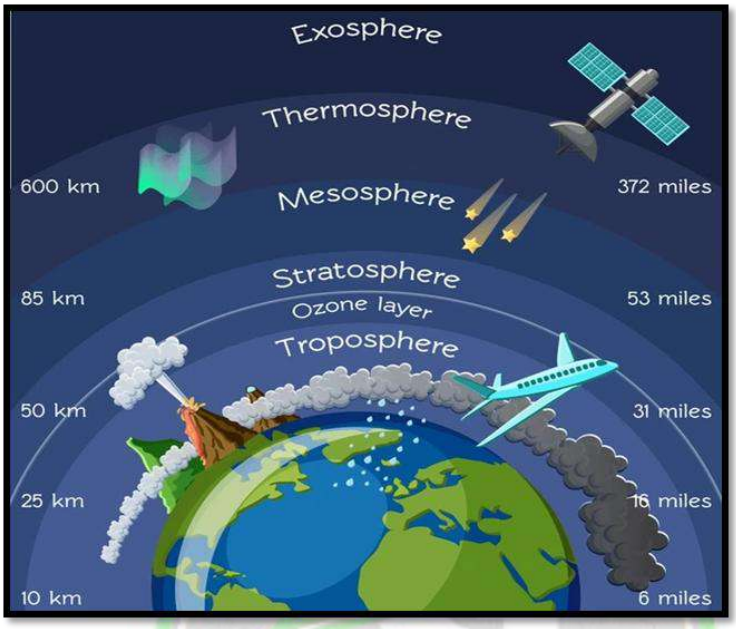
Effect of Different Ozone Layers on Seed Germination:

EXOSPHERE:

Seed germination is primarily influenced by factors like moisture, temperature, and light, in essence, the exosphere's impact on seed germination is indirect and minimal

THERMOSPHERE:

It is characterized by increasing temperature with altitude due to the absorption of high-energy solar radiation.



It also contains the ionosphere, which can affect radio wave propagation. However, these properties are not relevant to seed germination. But, changes in climate (influenced by atmospheric conditions) can indirectly affect seed germination through changes in temperature and precipitation patterns.

MESOSPHERE:

The mesosphere's influence on seed germination is indirect effects like Temperature, UV Radiation, Noctilucent Clouds (NLCs) and minimal compared to other factors like temperature, moisture, and light.

STRATOSPHERE:

Stratosphere itself doesn't directly influence seed germination, the UV radiation filters can negatively impact seeds and changes in the stratosphere, like ozone depletion, could indirectly impact seeds by increasing UV radiation levels. Excessive UV-B and especially UV-C radiation can damage DNA and cellular structures, potentially hindering or preventing germination.

TROPOSPHERE:

The troposphere's temperature and humidity levels directly influence the rate of seed germination.

Tropospheric ozone - a component of smog, can damage plants and reduce crop yields, including negative effects on seed Germination.

Sowing depth – Planting too shallow or too deep can hinder germination due to moisture or temperature issues.

Radiation - Increased radiation, due to a thinning atmosphere, can also negatively impact seed germination and plant growth by damaging the seed coat and affecting cellular processes.

EFFECT OF OZONE LAYER IN GREEN GRAM:

Ozone Depletion leads to increased ultraviolet (UV) radiation reaching the Earth's surface, which can negatively affect green gram. Specifically, increased UV-B radiation can reduce photosynthesis, stunt growth, and decrease yield quality and quantity.

Conclusion

The ozone layer plays an essential role in regulating the amount of ultraviolet (UV) radiation that reaches the Earth's surface. When the ozone layer is depleted, increased UV-B radiation can adversely affect seed germination. This can lead to delayed germination, reduced germination rates, and poor seedling development due to DNA damage, impaired cellular processes, and disrupted metabolic activity. Therefore, maintaining the integrity of the ozone layer is vital not only for human and animal health but also for supporting healthy plant life and agricultural productivity. The protection of the ozone layer is directly linked to the successful germination and growth of seeds, which are foundational to ecosystems and food security.

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EIGHT MEDICINAL MUSHROOM- DESCRIPTION, KEY COMPOUNDS. HEALTH BENEFITS

Article ID: AG-V05-I08-140

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Abstract

Medicinal mushrooms have attracted increasing attention due to their diverse health benefits and therapeutic compounds. This overview explores eight important species: Chaga, Cordyceps, Red Reishi, Lion's Mane, Shiitake, Turkey Tail, Oyster Mushroom, and Hen-of-the-Wood. These fungi are rich in bioactive constituents, including polysaccharides (especially β-glucans), triterpenoids, sterols, phenolic compounds, and unique elements such as cordycepin, erinacines, and lentinan. Their medicinal properties include anti-cancer, antioxidant, anti-inflammatory, antiviral, immune-modulating, and neuroprotective effects. Additionally, many of these mushrooms support heart health, help manage blood sugar levels, and contribute to cellular longevity. With a long history in traditional healing practices, current scientific research continues to confirm their potential benefits. As both nutritious food sources and functional medicines, these mushrooms serve as vital components in natural health products, supplements, and integrated healthcare systems.

Key words: Triterpenoids, Sterol, Phenolic compound, Polyphenol, β-glucans

Introduction

Mushrooms are spore-producing fruiting bodies that emerge from the ground or the fungus's food substrate. The Basidiomycetes class and the Agaricales order. Medicinal mushrooms have long been used to treat many different age-related diseases. Of the 2000 varieties of mushrooms, only 200 have been identified as edible. Traditionally used in systems

like Traditional Chinese Medicine (TCM) and Ayurveda, mushrooms such as Reishi, Lion's Mane, Chaga, Cordyceps, and Turkey Tail are rich in compounds like beta-glucans, antioxidants, and triterpenoids. These substances combat oxidative stress and promote cellular well-being. Available as powders, capsules, tinctures, teas, and even infused in foods and beverages, they are versatile and easy to incorporate into daily routines. Additionally, mushrooms provide valuable nutrients, including protein, dietary fiber, B vitamins, selenium, and potassium. They help maintain balance within the body and boost essential systems like the immune, nervous, and hormonal networks

1) Chaga Mushroom (*Inonotus obliquus*)

Also known as "Mushroom of Immortality," Chaga is a highly nutritious wild fungus that grows parasitically on birch trees. It forms a blackened, charcoal-like mass with a dense brown interior. The outer sclerotium is especially rich in melanin and contains very high oxalate levels, ranging from 2800 to 11200 mg per 100g, among the highest.

Key Compounds: β-glucans, triterpenoids (e.g., inotodiol, betulin, betulinic acid), polyphenols, melanin, lanosterol

Health Benefits: Cellular protection, immune enhancement, blood sugar regulation, anti-inflammatory, antioxidant, anti-cancer, supports longevity, and pathogen resistance.

2) Cordyceps (*Ophiocordyceps sinensis*)

Cordyceps is a parasitic fungus that invades insect hosts, particularly caterpillars. It forms a dark stalk (stroma) that protrudes from the insect's body, with a fungal core growing inside.

Key Compounds: Cordycepin, β-glucans, galactomannans, ergosterol, peptides (cordymin), essential amino acids, linoleic and oleic acids, B vitamins, selenium, zinc

Health Benefits: Anti-cancer, antiviral, immune support, fatigue reduction, improves oxygen efficiency, heart protection, anti-inflammatory, antifungal, boosts libido, regulates blood sugar and cholesterol

3) Red Reishi (*Ganoderma lucidum*)

Other names like Lingzhi and the "Life Elixir," Red Reishi is a shiny, woody mushroom with a bitter flavor and concentric rings on its cap

Key Compounds: Ganoderic acids, lucidone, ganodermadiol, β-glucans, ergosterol, ganoderol, adenosine, peptidoglycans, phenolics

Inonotus obliquus

Lentinula edodes

Ophiocordyceps sinensis

Trametes versicolor

Ganoderma lucidum

Pleurotus ostreatus

Hericium erinaceus

Grifola frondosa

Health Benefits: Antitumor, liver detoxification, blood pressure control, immune enhancement, antiviral, antioxidant, anti-aging, aids sleep, and reduces inflammation.

4) Lion's Mane (*Hericium erinaceus*)

pom-pom or cauliflower-like shape with soft, white to yellow spines, Lion's Mane grows on decaying hardwoods in temperate regions.

Key Compounds: Erinacines, hericenones, β-glucans, ergosterol, **Dilinoleoyl-phosphatidylethanolamine** (DLPE), lectins

Health Benefits: Stimulates nerve growth factor (NGF), enhances cognitive function, immune support, anti-aging, neuroprotection, anti-inflammatory, and antioxidant.

5) Shiitake (*Lentinula edodes*)

These tan to dark brown colour, umbrella-shaped mushrooms grow in decaying hardwood trees.

Key Compounds: Lentinan, eritadenine, lenthionine, various β-glucans, xylomannans, ergosterol, polyphenols, Heteroglycans

Health Benefits: Lowers bad cholesterol (LDL), supports heart and liver health, antimicrobial, enhances circulation, regulates blood pressure, antioxidant, and anti-cancer.

6) Turkey Tail (*Trametes versicolor*)

Turkey tail is a common type of polypore mushroom found around the world. It causes white rot in the sapwood and typically grows in dense, overlapping clusters or rosette shapes on logs and tree stumps.

Key Compounds: PSK (Krestin), Polysaccharopeptide (PSP), sterols, flavonoids, phenolics

Health Benefits: Immune enhancement, anti-cancer, antiviral, antioxidant, liver protection, inflammation reduction, and supports healthy cells.

7) Oyster Mushroom (*Pleurotus ostreatus*)

With a wide, fan-shaped cap, Oyster mushrooms come in shades from white to brown and smooth surface and an inrolled margin when young.

Key Compounds: Lovastatin (Polyketide), triterpenoids, peptides, β-glucans, Lectins, Phenolics

Health Benefits: Lowers cholesterol, promotes cardiovascular health, strengthens the immune system, is anti-inflammatory, antioxidant, antiviral, and helps regulate blood pressure.

8) Hen-of-the-Wood (*Grifola frondosa*)

It's a cluster of several grayish-brown mushroom caps, often curled or shaped like spoons, with wavy edges. Grows from an underground, potato-sized, tuber-like structure called a sclerotium.

Key Compounds: D-Fraction(β-glucan-protein complex), MD/SX-Fraction (β-glucan derivatives), β-glucans, ergosterol, grifolin, phenolics

Health Benefits: Supports liver and heart function, lowers cholesterol and blood sugar, boosts the immune system, antioxidant, anti-inflammatory, and has potential anti-cancer effects.

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WATER QUALITY INDICATORS IN INLAND AQUACULTURE

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Abstract

Water is the most important factor for aquatic life as well as human being. The physical, biological, and chemical conditions of water affect the various activities in aquatic life such as fish growth, reproduction, swimming, spawning and metabolism. The various water quality indicators include – temperature, turbidity, transparency, water color, dissolved oxygen, carbon dioxide, alkalinity, hardness, pH, ammonia, nitrite, nitrate, primary productivity, biological oxygen demand (BOD) and plankton population. Effective management, monitoring and regulating all these parameters through aeration, liming, water exchange, feeding control, and bio filtration not only optimizes water quality but also enhances overall pond productivity and environmental sustainability.

Key word- Primary productivity, phytoplankton, macrophytes, periphyton, photosynthesis, ecosystem function.

Introduction

One important natural resource is water. The health, growth, reproduction, and survival of aquatic species under cultivation are all directly impacted by water quality, making it a critical factor in inland aquaculture. Maintaining ideal water quality is crucial for aquaculture operations to be successful since fish and other aquatic species are totally reliant on their aquatic environment. The physical, biological, and chemical conditions of water in which they perform their daily activities—such as feeding, swimming, spawning, metabolism, fish body development, and excretion. These conditions also serve as an inexpensive source of protein and are acceptable for the distribution and production of fish and other aquatic organisms. Temperature, pH, and dissolved oxygen (DO) are main aspects of the water quality environment

that are becoming increasingly significant as the aquaculture business grows quickly in many nations. Water quality characteristics in which all living organisms operate optimally have acceptable limitations. Within these parameters, a rapid decline or increase has negative consequences for essential physiological health of the aquatic organism (Davenport, 1993: Kiran, 2010).

Types of Water Quality Indicators

Water quality indicators are physical, chemical, and biological parameters that help assess the suitability of water for supporting healthy fish populations in aquaculture and natural fisheries. Monitoring these indicators is essential for maintaining optimal conditions for fish survival, growth, and reproduction. The water quality indicators include – temperature, turbidity, transparency, water color, dissolved oxygen, carbon dioxide, alkalinity, hardness, pH, ammonia, nitrite, nitrate, primary productivity, biological oxygen demand (BOD) and plankton population.

1. **Physical indicators**

Temperature

According to Lucinda and Martin (1999), temperature is the degree of hotness or coolness in aquatic creatures. Since freshwater fishes are exotherms and cannot physiologically control their body temperature, their body temperature is influenced by their surroundings (Moyle & Cech, 2004). Some adapt behaviorally by shifting to microhabitats that are either warmer or colder, depending on the ambient range. Temperature fluctuations have a direct impact on fish physiology, including growth, reproduction, and activity, because biochemical responses are dependent on body temperature.

Turbidity

A measurement of the cloudiness or haziness of water brought on by suspended particles such silt, clay, organic debris, algae and microscopic organisms called turbidity. These particles scatter and absorb light, reducing the clarity of the water. Turbidity is the important factor of water quality because it influences the amount of sunlight that can reach aquatic plants and algae, which affects photosynthesis and oxygen production. High turbidity levels can reduce dissolved oxygen, hinder fish feeding (especially in sight-feeding species), clog gills, and increase the risk of disease by providing shelter to harmful microorganisms.

Transparency

Transparency is a measure of how clearly light can pass through water. It indicates the

depth to which sunlight can penetrate the water column and is closely related to the amount of suspended particles and plankton present in the water. Transparency is a key indicator of water quality and productivity. Clear water with high transparency allows deeper light penetration, which supports photosynthesis by aquatic plants and phytoplankton, leading to higher oxygen production. While low transparency (cloudy water) frequently indicates the presence of abundant plankton, suspended soil particles, or organic matter, which can cause oxygen depletion, stress in fish, or algal blooms.

Water Color

In aquaculture and fisheries, water color is a crucial physical indicator of water quality. It offers visual cues regarding the water body's biological productivity and the presence of dissolved or suspended materials. Green and brown shades are the common water color depending on the dominant materials present.

A green color indicates the presence of phytoplankton, which supports the natural food chain and helps in the generation of oxygen through photosynthesis.

A brown color indicates the high turbidity due to suspended particles, reduce photosynthesis.

2. **Chemical indicators**

Dissolved oxygen (DO)

A crucial indicator of bacterial activity, photosynthesis, nutrients, and stratification is dissolved oxygen (DO) (Premlata, 2009). Summertime temperatures and microbial activity cause DO to drop, although phytoplankton photosynthesis supplies oxygen (Krishnamurthy, 1990). The physiology, growth, survival, and distribution of aquatic animals are all impacted by DO (Solis, 1988). Low DO slows metabolism, stunts growth, and decreases feed efficiency; the ideal is >5 mg/L. Suffocation and death are possible for fish below 2 mg/L, particularly in the early morning.

Carbon dioxide

environments and its variation is often a measure of net ecosystem metabolism. Free carbon dioxide, a highly soluble gas in water created by animal respiratory process, is the main source of carbon cycle in nature. It can exist in water as carbonate and bicarbonate form. When carbon dioxide react with water it produce carbonic acid, which reduces pH of any system, those with inadequate buffering, and aquatic animals may suffer as a result of lowered pH.

Alkalinity

The total alkalinity is defined as the total concentration of bases in water. The common bases in natural waters are hydroxide, carbonate, bicarbonate, silicate, borate, phosphate, and ammonia. But, in most natural waters, and especially in waters of aquaculture systems, bicarbonate contributes most of the alkalinity at pH $\leq$ 8.3, while carbonate, and sometimes hydroxide, contribute to alkalinity at greater pH. It measures the buffering capacity of water and the availability of inorganic carbon for photosynthesis by aquatic plants are related closely to this variable (Boyd et al., 2016). Alkalinity also acts as a stabilizer for pH.

The water becomes more acidic due to low alkalinity, which might affect fish immune response, eating, respiration and reproduction. On the other side particularly in productive ponds with dense phytoplankton development, very high alkalinity can result in an unnecessarily high pH, which can also be harmful to fish.

Hardness

The primary cause of hard water is dissolved calcium and magnesium, which are measured in milligrams per liter of calcium carbonate. Slightly hard (<60 mg/L), moderately hard (60–120 mg/L), hard (120–180 mg/L), very hard (>180 mg/L), and soft (<17.1 mg/L) are its classifications. Calcium helps fish's blood coagulate, muscles contract, neurons, bones, and scales. The toxicity of ammonia and heavy metals is decreased and pH is stabilized by enough hardness, whereas inadequate hardness leads to stress, stunted growth, weak reproduction, and an increased risk of disease.

pH

pH is a measure the negative logarithm of the hydrogen ion concentration [-H+] in a solution, which indicates how acidic or basic (alkaline) the water is. It is expressed on a scale ranging from 0 to 14. pH is probably by far the most important physicochemical parameter controlling the behavior of other water quality parameters as well as metals concentration in the aquatic environments, pH may also influence the lives of bacteria and the availability of other contaminants in water. In general, very high or very low pH can make water unpleasant for certain purposes. At very high pH, metals tend to precipitate while chemicals such as ammonia become toxic to aquatic life; water tend to have unpleasant smell and taste in alkaline conditions (Saalidong et. al, 2022). At low pH, solubility of metals tend to be high, chemicals like cyanide and sulphide become more toxic.

Ammonia (NH_3)

Nitrogen consists of un-ionized ammonia and ammonium, which are pH- and temperature-dependent. Ammonium is important for phytoplankton growth. A large amount of ammonia nitrogen enters the aquatic environment via anthropogenic discharges such as municipal effluent discharges and agricultural runoff. This can lead to severe and even irreversible effects on aquatic ecosystems cause negative impacts on fish growth, gills and reproductive function.

Nitrite (NO_2^-)

Nitrite is a residue of the aerobic nitrification bacterial process, which is formed by the autotrophic Nitrosomonas bacteria when oxygen and ammonia are combined. High nitrite levels are hazardous in aquaculture and fisheries because they are easily absorbed by the fish's gills and enter the bloodstream, where they combine with hemoglobin to generate methemoglobin. This disorder called brown blood disease.

Nitrate (NO_3^{2-})

Nitrogen consists of un-ionized ammonia and ammonium, which are pH- and temperature-dependent. Ammonium is important for phytoplankton growth. A large amount of ammonia nitrogen enters the aquatic environment via anthropogenic discharges such as municipal effluent discharges and agricultural runoff. This can lead to severe and even irreversible effects on aquatic ecosystems (Lin et. al, 2019). Fish with high nitrate level (more than 100 ppm) may cause chronic stress, reduced growth, decreased feeding efficiency and impaired reproduction.

3. Biological indicators

Primary productivity

Aquatic food chains are based on primary productivity, which is the rate at which producers transform inorganic carbon into organic matter (Parag Deka, 2017). During photosynthesis, keystone species such as macrophytes, periphyton, and phytoplankton that possess chlorophyll produce organic molecules and release oxygen. They help higher trophic levels by stabilizing and transferring energy. An important metric for evaluating ecosystem function is the rate at which phytoplankton fix organic carbon, which indicates the system's productivity (Odum, 1971).

Biological Oxygen Demand (BOD)

BOD is a measure of organic material contamination in water, specified in mg/L. BOD is

the amount of dissolved oxygen required for the biochemical decomposition of organic compounds and the oxidation of certain inorganic materials (e.g., iron, sulfites). Typically the test for BOD is conducted over a five-day period.

Plankton population.

Plankton is important members of the aquatic food web. The plankton includes phytoplankton or algae (microscopic plants) and zooplankton (tiny shrimp like animals that eat algae). The phytoplankton is primary producers that convert light energy from the Sun to plant tissue through the process of photosynthesis. This forms the foundation of the aquatic food chain. Small microscopic shrimp-like crustaceans called zooplankton eat the phytoplankton. In turn, the zooplanktons are extremely important food for young fish. The phytoplankton are organized taxonomically largely by colour. Important phyla (groups) include: Cyanobacteria (blue-green algae), Chlorophyta (green algae), Chrysophyta (yellow-brown algae) and Bacillariophyta (diatoms). (Gorde and Jadhav, 2013).

Monitoring and Management Practices

- Absorbed and routine testing of all water parameters in weeks or months.
- Use of aerators, to maintain dissolved oxygen level.
- Use lime, probiotics for the production of natural food organisms for cultured species.
- Exchange water in months to maintain pH level.

Conclusion

The effectiveness and sustainability of inland aquaculture systems are significantly influenced by water quality indicators. Parameters such as temperature, dissolved oxygen, pH, alkalinity, hardness, ammonia, nitrite, nitrate, turbidity, and biological factors directly influence the physiological health, growth, survival, and reproductive efficiency of cultured fish. These indicators are depend on each other and slight imbalances can lead to stress, reduced feed intake, increased disease susceptibility, and mass mortalities. Properly management of these parameters helps in detection of problems and ensures corrective measures. Effective management through aeration, liming, water exchange, feeding control, and biofiltration not only optimizes water quality but also enhances overall pond productivity and environmental sustainability.

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CRISPR-CAS9 APPLICATIONS IN AQUACULTURE: ADVANCES AND ETHICAL CONCERNS

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Abstract:

There is increasing pressure on the aquaculture sector to satisfy the world's food needs while reducing resource constraints, disease outbreaks, and environmental effects. In aquaculture, the specific genome editing technology CRISPR-Cas9 has opened up new avenues for targeted modifications to enhance economically relevant traits (Jinek et al., 2012; Zhang et al., 2018). This work presents advances in growth enhancement, disease resistance, and control of reproduction by integrating the latest applications of CRISPR-Cas9 in aquaculture species including *Oreochromis niloticus* (tilapia) and *Channa spp.* The ethical, ecological, and regulatory concerns in gene editing aquatic organisms are severely being evaluated (Van Eenennaam, 2019; Zayats et al., 2021). This article attempts to make a balanced evaluation of the appropriate integration of CRISPR-Cas9 in aquaculture systems by describing current advances and future potential.

Key points: Aquaculture, CRISPR, Growth, Immunity, Reproduction, Tilapia

Introduction

In the last decades, world aquaculture has developed exponentially, currently offering over half of the entire fish consumption of the globe (FAO, 2022). Gene editing is one of the latest biotechnological technologies enabling scientists to make precise modifications to an organism's DNA, i.e., adding, removing, or modifying specific genes in order to achieve desired traits. In aquaculture animals, these edits can be made to improve growth performance, immunity to viral,

bacterial, and parasitic diseases, tolerance to temperature or salinity changes, and even nutritional content, e.g., enhancing omega-3 fatty acid content. In contrast to conventional breeding, which relies upon incremental genetic gain over many generations, gene editing permits accurate and predictable modification in much less time. Several genome editing technologies have been designed—namely, Zinc Finger Nucleases (ZFNs), Transcription Activator-Like Effector Nucleases (TALENs), and very recently, CRISPR-Cas systems—with CRISPR being easy to use, efficient, and cost-effective. But the limitations of traditional selective breeding approaches are environmental heterogeneity, polygenic characteristics, and long generations. With precise and heritable genetic modifications, genome editing, and particularly the CRISPR-Cas9 system, now holds unparalleled promise to overcome such limitations (Doudna & Charpentier, 2014; Zenger et al., 2019.

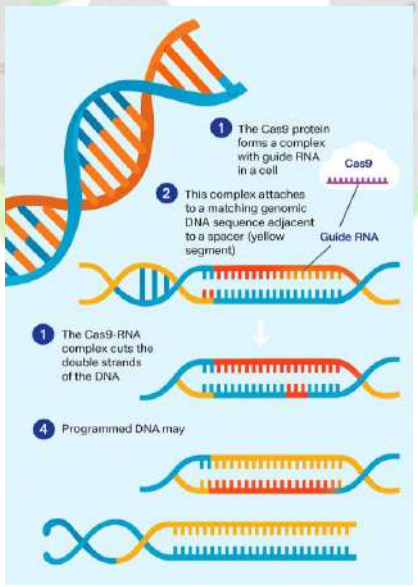
CRISPR-Cas9, originally found in prokaryotes as a prokaryotic adaptive immunity, allows for specific DNA cutting at user-defined positions, followed by homology-directed repair (HDR) for precise insertion or gene disruption (Jinek et al., 2012). Functional aquaculture genomics has been transformed by this, leading to improved traits in non-model and model fish species (Houston et al., 2020).

Overview of the CRISPR-Cas9 System

CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) is a bacterial and archaeal adaptive immune system that enables them to recognize and destroy foreign viral genetic material. This natural process has been exploited as a very versatile genome-editing technology due to its ease of use, precision, and efficiency. The system is used in combination with CRISPR-associated (Cas) proteins, which act as molecular scissors to cut nucleic acids. A number of Cas proteins have been recognized with different characteristics: Cas9 cuts double-stranded DNA and is the most popular in use for genome editing; Cas12 cuts double-stranded DNA but makes staggered incisions and can be utilized in editing as well as diagnostics; Cas13 targets RNA, enabling transient gene expression regulation without DNA modification; and Cas14 is specialized for cutting single-stranded DNA, which has application in sensitive nucleic acid detection. Of these, the CRISPR-Cas9 system from *Streptococcus pyogenes* is the most common in research and biotechnology. In CRISPR-Cas9, a guide RNA (gRNA) directs the Cas9 nuclease to a complementary sequence of DNA, where Cas9 induces a double-strand break. The break can be repaired by either homology-directed repair (HDR), which allows for accurate

sequence insertion or correction, or non-homologous end joining (NHEJ), which frequently results in gene disruption or deletion (Cong et al., 2013).

CRISPR-Cas9 has been quickly embraced in aquaculture research because it is easy, efficient, and can multiplex, making it possible to employ targeted breeding strategies and functional annotation of genes (Hsu et al., 2014; Zenger et al., 2019). Its cost-effectiveness, with its plasticity in being versatile in a broad spectrum of species, makes it highly compatible with non-model aquaculture species where genomic resources are usually not available. The technology allows for precise genetic manipulations for attributes like disease resistance, stress tolerance, growth promotion, and enhanced feed use efficiency that are vital in the creation of sustainable aquaculture. Moreover, CRISPR-Cas9 also allows rapid generation of homozygous lines with reduced generation intervals compared to traditional breeding. Its application also includes functional genomics studies with the ability to examine gene function in development, physiology, and environmental adaptation. When combined with high-throughput sequencing and transcriptomics, CRISPR-based editing offers unprecedented opportunities for trait improvement and conservation breeding schemes in aquaculture.



CRISPR cas9 gene edition

Applications of CRISPR-cas9 gene edition tool in Aquaculture:

Growth Performance

Another well-established negative muscle growth regulator, myostatin (MSTN) gene, has been successfully targeted in tilapia with CRISPR-Cas9. With no influence on viability or

fertility, the majority of knockouts showed an increase in muscle fiber diameter and overall body weight (Li et al., 2021; Zhong et al., 2022). Such genetic improvements not only enhance feed conversion ratio and shorten time to market but also enhance fillet yield, which is highly important in order to fulfill consumers' demand for lean protein. Moreover, multiplex editing approaches have been aimed at metabolic regulatory genes like *gh* (growth hormone) and *igf1* (insulin-like growth factor 1) in order to synergistically augment somatic growth (Xu et al., 2023). By improving feed conversion and reducing culture durations, these changes can have considerable environmental and economic benefits, reducing inputs per unit of harvested biomass.

Disease Resistance

Genome editing for the improvement of innate immunity has been considered in tilapia aquaculture.CRISPR-Cas9 has shown increased resistance to *Streptococcus agalactiae* and *Aeromonas hydrophila* through the targeting of pattern recognition receptors (e.g., TLR2, TLR5) and cytokine-related genes (e.g., il1β, tnfα) (Zhang et al., 2022; Wang et al., 2023). Apart from bacterial pathogens, studies have started targeting viral issues like Tilapia Lake Virus (TiLV), and editing the antiviral genes *Mx* and *ISG15* has been proving effective in initial tests (Chen et al., 2024). These genetic changes increase survival during epidemics, enhance production stability, and lower the reliance on antibiotics and chemical treatment, hence making contributions towards environmentally friendly and sustainable agricultural practices.

Reproductive Control

Unchecked reproduction in tilapia farming can lead to stunted growth and, when fish escape, cause environmental issues. Sex reversal and generation of sterile lines have been facilitated through the silencing of genes like *dmrt1* (male sex determination) and *cyp19a1a* (aromatase), offering a biosafety means for open aquaculture systems (Wang et al., 2020; Qin et al., 2021). In addition, CRISPR-Cas9 knockout of germ cell development genes, like *vasa* and *dnd1*, has been explored to create functionally sterile fish with normal somatic growth (Hu et al., 2023). This method not only enhances growth uniformity but also reduces genetic introgression threats if escape farmed tilapia into wild environments. Combining selective growth trait breeding with reproductive confinement offers a double advantage—increasing yield while safeguarding biodiversity.

Thermal and Hypoxia Tolerance

Stressors due to climate change like increased temperatures and hypoxia have triggered explorations of heat shock proteins (HSPs) and hemoglobin genes. Initial CRISPR experiments targeting *egl9* homologs and *hsp70* presented enhanced survival during thermal stress, but field testing is still awaited (Rao et al., 2023). More experimental research is investigating concurrent editing of multiple hypoxia-inducible genes to achieve improved resilience under varying oxygen levels. As a result of their natural air-breathing ability, additional genomic fine-tuning may make *Channa spp.* A perfect aquaculture species for low-water-exchange or high-density systems, saving aeration costs and farm sustainability.

Immunomodulation

One of the largest issues in snakehead aquaculture is susceptibility to disease. To establish disease-resistant strains, genome editing of significant immune-associated genes, such as *tlr9* and interferon regulatory factors (IRFs), is currently underway. Quick progress, however, is hindered by a shortage of genetic resources (Kumar et al., 2022). Scientists are further looking into CRISPR-mediated interference with viral entry receptors to avoid popular pathogens like iridoviruses and *Aeromonas spp.* from the onset of infection. In addition, multiplex editing strategies are designed to merge pathogen-specific immunity with widespread disease tolerance, lowering reliance on antibiotics and vaccines in intensive production.

Conservation and Genetic Restoration

With assisted reproduction and cryopreservation techniques, CRISPR can also assist in the restoration of lost alleles within endangered wild *Channa* populations, which will have a bearing on conservation biology (Nguyen et al., 2021). Developments in germ cell transplantation and gene editing can be utilized to restore genetic diversity into isolated or declining populations. In addition, eDNA monitoring in combination with genomic mapping is capable of detecting residual populations with rare alleles, which are selectively bred using CRISPR-mediated breeding. These conservation applications may assist in the upkeep of the ecological function of *Channa spp.* in freshwater habitats as well as in supporting small-scale fisheries based on them.

Ethical, Ecological, and Regulatory Considerations of CRISPR tool:

Environmental Risk

The deliberate or accidental release of gene-altered fish into the natural environment

poses threats of ecological imbalance, introgression in the wild population, and unanticipated evolutionary effects. Such threats may occur in the form of modified predator–prey dynamics, nutrient cycling changes, or competitive replacement of indigenous species (Kapuscinski & Hallerman, 1991). Sterility and confinement techniques, for example, triploidy induction and land-based Recirculating Aquaculture Systems (RAS), are necessary measures to limit ecological spillover (Devlin et al., 2006; Van Eenennaam, 2019). Long-term ecological surveillance is required to determine cumulative impacts, especially where habitats are high in biodiversity and ecologically sensitive.

Off-Target Effects and Animal Welfare

Although CRISPR-Cas9 has great specificity, off-target mutations can occur and lead to unforeseen physiological or behavioral alterations, like different stress responses or reproductive failure. Unwanted changes in non-coding areas could also have regulatory impacts that are hard to anticipate (Fu et al., 2013). From the perspective of animal welfare, genome editing should not impose chronic pain, decreased fitness, or impaired adaptability. Before commercialization, multi-generational breeding trials and whole-genome sequencing, followed by rigorous validation procedures, are required (Tsai & Joung, 2016; Zayats et al., 2021). Ethical review boards in aquaculture studies can guarantee humane treatment and reduce suffering during experimental trials.

Consumer Acceptance

Market acceptability and public opinion remain barriers. Consumer mistrust can be caused by misconceptions about genetic modification, perceived "unnaturalness," and food safety issues (Frewer et al., 2013). Confidence can be established through ethical certifications, public engagement, and open labelling, especially in regions where genetic modification is culturally sensitive (Muringai et al., 2020). Stakeholder dialogues involving participation of fishers, farmers, policymakers, and consumers can mitigate resistance. Providing tangible advantages like lower antibiotic utilization, better nutrition, and smaller environmental footprint can also shape favorable public opinion.

Regulatory Landscape

The regulation of CRISPR-edited organisms varies significantly across countries, reflecting differences in scientific capacity, public perception, and governmental priorities. In the European Union, a strict stance is adopted: following the 2018 European Court of Justice ruling,

all gene-edited organisms are classified under the GMO framework. In contrast, the United States distinguishes between transgenic organisms and certain CRISPR-edited species that do not involve foreign DNA, with the latter excluded from conventional GMO regulations (Ishii & Araki, 2017; USDA-APHIS, 2020).

Japan applies a product-based approach, exempting organisms from GMO labeling if no foreign DNA remains in the final product, though it encourages voluntary transparency (Matsuo, 2019). Similarly, Argentina, Brazil, and Chile adopt case-by-case, product-oriented regulatory models, which have accelerated commercial testing in aquaculture species (Whelan et al., 2020). In China, the world's leading aquaculture producer, draft regulations for gene-edited organisms aim to balance innovation incentives with biosafety concerns, though comprehensive enforcement frameworks are still evolving (Huang et al., 2021). Australia and New Zealand also allow certain gene-editing applications to bypass full GMO evaluation when no recombinant DNA is retained, enabling faster approvals for traits such as disease resistance in aquatic species (OGTR, 2019).

In India, gene-edited organisms are governed by the *Environment (Protection) Act, 1986* and the *Rules, 1989* on hazardous microorganisms and genetically engineered organisms. Oversight rests with the Genetic Engineering Appraisal Committee (GEAC) and the Department of Biotechnology (DBT). DBT's 2022 guidelines proposed a tiered system: SDN-1 and SDN-2 edits (which do not involve foreign DNA) are excluded from GMO classification, while SDN-3 edits (involving foreign DNA insertion) remain fully regulated as GMOs (DBT, 2022). While this provides a clearer pathway for agricultural applications, aquaculture-specific guidelines are still lacking. The absence of defined biosafety trials, environmental release protocols, and species-focused risk assessment frameworks creates regulatory uncertainty for fish genome editing (Raman, 2017).

Future Perspectives and Recommendations

- **Multi-gene editing**: To target several features at once, including growth, immunology, and stress tolerance, future research should focus on multiplex CRISPR techniques (Zhou et al., 2020).
- **Integration with Omics**: In non-model species such as *Channa spp*., CRISPR can speed up the finding of functional genes by combining it with transcriptomics and proteomics (Yáñez et al., 2015).

- **Field Experiments**: To evaluate cost-benefit results, ecological safety, and long-term phenotypic stability, controlled semi-open field assessments are required.
- **Frameworks:** To create bioethical norms and involve stakeholders such as farmers, consumers, and policymakers, institutions should work together (NASEM, 2017).

Conclusion

A paradigm breakthrough in aquaculture biotechnology, CRISPR-Cas9 provides accurate and long-lasting answers to persistent problems in fish breeding. Genome editing can improve the health, productivity, and environmental compatibility of animals like tilapia and *Channa spp*. However, ethical forethought, public trust, and clear regulations are just as important to success as technological advancements. The technology's legacy in international aquaculture will be determined by an inclusive and responsible attitude as it develops.

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LIGHT POLLUTION AND INSECT BEHAVIOUR: THE UNSEEN ECOLOGICAL IMPACT

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Abstract

As urbanization intensifies, artificial lighting has become a defining feature of modern landscapes, leading to a growing but often underestimated ecological challenge: light pollution. Although its consequences for astronomy and human circadian health are well-documented, the broader ecological implications—particularly those affecting insect populations—have only recently gained attention in scientific research. Insects play critical roles in ecosystems as pollinators, decomposers, prey, and natural pest regulators, making them highly influential to ecological stability and biodiversity. However, their reliance on natural light cues for navigation, mating, foraging, and migration renders them especially vulnerable to the effects of artificial light at night (ALAN) and polarized light reflections from urban surfaces. This paper synthesizes current research to examine how these forms of light pollution disrupt insect behavior, physiology, reproduction, and survival. Furthermore, it explores cascading effects on food webs, plant-pollinator networks, and ecosystem services. By analyzing impacts from the molecular to the ecosystem level, this study aims to illuminate the complex and often overlooked ecological footprint of light pollution. The findings emphasize the urgent need for environmentally informed lighting practices in urban planning and conservation strategies to mitigate the long-term ecological consequences of artificial illumination.

Keywords: Light pollution, Insects, ALAN and Insects

Introduction

As urbanization accelerates and artificial lighting becomes increasingly embedded in modern life, an invisible ecological pressure is intensifying—light pollution. While its effects on astronomy and human circadian rhythms have garnered significant attention, the ecological ramifications, particularly on insect populations, are only beginning to emerge in scientific discourse. Insects—vital to ecosystems as pollinators, decomposers, prey, and natural pest controllers—are highly sensitive to natural light cues. The intrusion of artificial light at night (ALAN) and the widespread presence of polarized light reflections in urban landscapes significantly disrupt insect behavior, physiology, and ecological functions. This paper explores the often-overlooked ecological footprint of light pollution through the lens of recent research, revealing its impacts from the molecular level to entire ecosystems.

The Science of Light Pollution

Light pollution encompasses multiple forms of unnatural illumination. Two major types affecting insects are:

1. Artificial Light at Night (ALAN): This includes street lights, building illumination, advertising displays, and vehicle headlights. ALAN disrupts the natural photoperiod to which nocturnal and crepuscular insects are evolutionarily adapted.
2. Polarized Light Pollution**:** Caused by light reflecting off manmade surfaces such as glass buildings, asphalt, solar panels, and vehicles. Many insects rely on horizontal polarization patterns for navigation and locating water bodies.

Both forms interfere with natural behavioural patterns, often leading to physiological stress, ecological misplacement, and population-level consequences.

Behavioural Disruption in Insects

Insects use light for multiple vital behaviours, including orientation, mating, migration, foraging, and oviposition. Light pollution also misguides the following instincts:

- Navigation and Orientation: Many insects are positively phototactic, meaning they move towards light sources. Under natural conditions, they use moonlight or starlight for navigation. However, intense point sources such as streetlamps create disorientation, causing them to spiral around lights or become trapped in illuminated areas. This leads to energy depletion and increased predation.
- Oviposition Errors: Aquatic insects like mayflies and caddisflies mistake smooth, dark,

horizontally polarized surfaces (e.g., car roofs or bitumen roads) for water. This results in mass egg-laying on unsuitable substrates, leading to zero reproductive success and population decline.

- Disrupted Courtship: Fireflies, glow-worms, and moths use bioluminescence or pheromonal trails for mate attraction. ALAN interferes with these signals, reducing mating opportunities. For example, glow-worm females become less visible under streetlight conditions, leading to reproductive failure.
- Foraging Behaviour**:** Insect pollinators, particularly nocturnal moths, are distracted or repelled by artificial lights. This affects their ability to locate flowers, disrupting pollination networks and indirectly harming plant reproduction

Physiological Impacts of Light Pollution

Light not only affects behaviour but also interacts with insects' internal biological clocks (Circadian Rhythm)

- Circadian Rhythm Disruption: Many insects, like other animals, follow circadian rhythms regulated by the light-dark cycle. Artificial lighting confuses these rhythms, altering the timing of activity, hormone release, molting, and feeding.
- Reproductive Hormone Imbalance: ALAN has been shown to suppress melatonin production in some insects and delay or inhibit hormonal cascades required for reproduction. This can reduce fecundity and viability of eggs.
- Developmental Delays and Morphological Changes: Continuous exposure to ALAN during larval stages may prolong development, result in malformed adults, or alter diapause timing, all of which affect survival and fitness.

Ecological and Trophic Consequences

Disruption at the individual level leads to cascading effects across food webs and ecological interactions:

- **Altered Predator-Prey Dynamics:** Insects clustered around lights are easy prey for predators like bats, frogs, and birds, skewing natural hunting patterns. Conversely, light-sensitive nocturnal predators may avoid lit areas, allowing certain pests to proliferate unchecked.
- **Pollination Breakdown:** Night-blooming plants depend on moths and beetles for pollination. ALAN decreases pollinator visits, leading to reduced fruit set and seed

production, ultimately impacting food webs that depend on these plants.

- **Community Composition Shifts:** Some generalist insect species adapt to lit conditions, while specialists and light-averse taxa decline. This homogenization reduces biodiversity and can lead to ecological imbalance.
- **Ecosystem Services Decline:** Insects play key roles in nutrient cycling, seed dispersal, soil aeration, and pest regulation. Disruption of these services due to light pollution can have long-term environmental and economic consequences.

Mitigation and Management Strategies

Given the growing awareness of light pollution's impact, several mitigation approaches are gaining attention:

- Lighting Design Innovations: Using warm-toned lights (<3000 Kelvin), shielding fixtures to direct light downward, and installing motion sensors can reduce unnecessary illumination.
- Timing Control: Switching off or dimming lights during off-peak hours (e.g., midnight to dawn) significantly reduces exposure for insects during their peak activity.
- Material Engineering: Urban planning can include the use of anti-reflective or non-polarizing surface coatings to reduce polarized light pollution. Examples include matte finishes on solar panels and adding white grids to roadways.
- Dark Sky Initiatives: Conservation areas and parks can adopt "dark sky" principles, ensuring minimal artificial lighting to preserve natural behaviours and biodiversity.
- Policy and Public Awareness: Light pollution is rarely regulated. Introducing guidelines at municipal and national levels, educating urban developers, and engaging citizens can create insect-friendly lighting environments.

Future Directions and Research Needs

The intersection of entomology and light pollution science is still evolving. Future research should:

- Explore species-specific responses to various light spectra and intensities.
- Investigate long-term evolutionary impacts of ALAN on insect populations.
- Quantify ecosystem service losses linked to disrupted insect functions.
- Develop interdisciplinary solutions involving engineers, ecologists, urban planners, and policymakers.

Conclusion

Light pollution represents an urgent but under-acknowledged threat to insect biodiversity and the ecological functions they support. From misdirected oviposition to disrupted courtship and cascading food web effects, artificial lighting disturbs a wide spectrum of insect life. The growing scientific evidence underscores the necessity of integrating ecological sensitivity into lighting design and urban development. As stewards of biodiversity, it is imperative that we illuminate our world responsibly—balancing human needs with the unseen but invaluable lives of insects

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UNLOCKING NEEM'S POTENTIAL: A BIOTECNOLOGICAL APPROACH TO MICROPROPAGATION

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Abstract

Neem *(Azadirachta indica A. Juss*.) is a well-known medicinal tree that is valued all over the world. Micropropagation in neem allows for the rapid and mass production of disease-free neem plants. By using small tissue samples such as shoot tips or nodal segments under sterile, controlled laboratory conditions, scientists can produce thousands of genetically uniform, disease-free neem plants in a relatively short period. These top-quality trees have been selected and grown in lab using micropropagation (a method to produce many copies of a plant). The process generally involves culturing explants with the nodal segments on a nutrient medium, promoting shoot proliferation and root formation, and then transferring the resulting plantlets to soil. The cultivation of neem has more advantage for reforestation, agroforestry, and medicinal purposes.

Key words: Neem, Micropropagation, Nodal Segment, Nutrient Medium

Introduction

Azadirachta indica A. Juss commonly referred as neem, is a prominent species within the Meliaceae family, which comprises approximately 51 genera and 575 species. known wildly as the Indian neem or Indian lilac. Often referred to as the "village pharmacy," neem has been traditionally used in Ayurveda and folk medicine for centuries, and its extracts are widely used in natural pesticides, cosmetics, and pharmaceuticals. Some neem trees have special qualities, like

producing a high amount of azadirachtin (a use**ful** natural compound). Renowned for its wide ranging applications and resilience ,the neem tree is often referred to by various names across different regions . the "tree of 21st century" in the United States, "Nature's drug store" or "Village dispensary" in India and the "Tree of forty" in parts of Africa . It is a fast growing evergreen perennial capable of withstanding high temperatures and drought conditions. Native to the Indian subcontinent , Neem is now extensively cultivated across many Asian countries due to its adaptability and the diverse range of medicinal, agricultural and industrial product it offers.

Importance of Neem

In traditional and modern medicine, neem exhibits antibacterial, antifungal, antiviral, anti-inflammatory, and antiparasitic properties, making it effective in the treatment of skin disorders, gastrointestinal ailments, dental issues, and chronic conditions such as arthritis. In agriculture, neem plays a significant role as a natural bio pesticide and fungicide due to the presence of bioactive compounds like azadirachtin. Neem oil, neem cake and leaf extracts are widely used to control insect pests and improve soil fertility, offering an eco-friendly alternative to synthetic agrochemicals. Industrially, neem derivatives are utilized in the formulation of soaps, cosmetics, personal care products, and pharmaceuticals. Additionally, neem contributes to environmental sustainability through its drought tolerance, capacity for afforestation, and utility in reforestation and erosion control projects. Its diverse pharmacological and ecological benefits underscore neem's importance as a cornerstone of traditional knowledge and sustainable development.

Tissue Culture as a Solution

Traditionally, neem (*Azadirachta indica*) is propagated through seeds. However, neem seeds are recalcitrant in nature and rapidly lose viability, thereby limiting their storage potential and long-distance distribution This posses a major constraint on the year-round availability of viable propagules. Moreover, due to the cross-pollinated nature of the species, seed propagation often results in high genetic heterogeneity making it unsuitable for maintaining elite traits. To overcome these limitations, various tissue culture techniques have been developed for the rapid clonal propagation of superior genotypes with high azadirachtin content. These methods enable consistent, large-scale multiplication of elite neem trees throughout the year, ensuring genetic uniformity and improved phytochemical yield

STEPS IN MICROPROPAGATION OF NEEM

1.Plant Material and Culture Preparation

To ensure successful micro propagation, explants should be collected from healthy, disease-free, and mature plants selected from actively growing shoots or tissues sterilized properly to prevent microbial contamination. Nodal segments were prepared for culture by removing the leaves and trimming them to a uniform length of 3 cm, optimizing the material for subsequent experimental procedures.

2.Surface Sterilization

Nodal segments and cotyledons were first treated with a solution of 0.1% bavistin for 8 hours and tween 20 for 10 mins, then followed by 2-4% sodium hypochlorite (NaOCl) for 15 minutes and they were briefly washed in 70% ethanol (30 seconds), and rinsed five times with sterile water .

3.Before placing them in culture:

Nodal cuttings were trimmed at both ends to expose fresh tissue. Cotyledons were placed with the flat side (ventral side) facing down on the culture medium.

4.Culture Medium and Growth Conditions

The culture medium and growth conditions explants (nodal culture) on full-strength Murashige and Skoog (MS) medium, supplemented with specific growth regulators and nutrients to support optimal growth and development.

5. Plant growth regulators:

Plant growth regulators were utilized to facilitate optimal growth and development in tissue cultures. Specifically, two types of cytokinins, BAP (6-Benzylaminopurine) and Kinetin, were employed at a concentration of 3.0 mg/L. These cytokinins were used either individually or in combination with an auxin, NAA (α-Naphthaleneacetic acid), at a concentration of 0.5 mg/L. The growth regulators were added to the culture medium, which was then adjusted to a pH of 5.7 to create an optimal environment for plant growth. To provide a solid substrate for the cultures, 8 g/L of agar was incorporated into the medium. Finally, the medium was sterilized through autoclaving at a temperature of 121°C for a duration of 20 minutes to eliminate any potential microbial contaminants. This rigorous preparation ensured a sterile and conducive environment for the nodal and cotyledon cultures to thrive.

6.Nodal cultures:

The nodal cultures were subjected to a controlled environment that fostered optimal growth and development. Specifically, they were placed under a consistent light/dark cycle, consisting of 16 hours of light followed by 8 hours of darkness. This photoperiod regime was maintained throughout the entire incubation period, providing the cultures with a stable and predictable light environment. The temperature was carefully regulated to ensure a consistent temperature of 25°C, with a tolerance of ±2°C, creating an ideal climate for plant growth. Additionally, the cultures were exposed to a moderate light intensity of 50 µmol m^{-2} s^{-1}, which was provided by fluorescent lights. These controlled conditions allowed the nodal cultures to undergo healthy growth and development, promoting the formation of shoots and roots. By maintaining a consistent and optimal environment, the chances of successful plantlet regeneration and establishment were significantly enhanced.

7.Shoot Multiplication

After 15 days, the first signs of shoot initiation (bud break) were observed in the induction medium. These cultures were then subcultured into the same medium. Individual shoots (2 cm long) from 5-week-old cultures were transferred to MS medium with BAP (1.5 mg/L), NAA (0.5 mg/L) and Casein hydrolysate (400 mg/L). This encouraged further shoot multiplication and elongation.

8.Rooting:

The rooting process was initiated by carefully selecting elongated shoots that had reached a length of approximately 4-5 cm. These shoots were then gently transferred to a specialized rooting medium, designed to promote root development and establishment. The rooting medium consisted of half-strength Murashige and Skoog (MS) salts, which provided the necessary nutrients for root growth. To further enhance root induction and development, the medium was supplemented with indole-3-butyric acid (IBA) at a concentration of 3 mg/L. IBA is a synthetic auxin that plays a key role in root initiation and development. Additionally, activated charcoal was added to the medium at a concentration of 200 mg/L, which helped to absorb any potential inhibitorsand promote healthy root growth. By providing the shoots with the optimal rooting conditions, the chances of successful root establishment and plantlet development were significantly increased

9.Hardening

Fully rooted plantlets with 5–7 leaves were taken out of the culture vessels, gently washed to remove agar, and dipped in 0.1% bavistin (a fungicide). They were transplanted into paper cups filled with a sand:soil:vermiculite mixture in equal parts (1:1:1). Cups were covered with transparent sheets for the first 10 days to maintain humidity. Once established, plants were moved to polybags and placed in a greenhouse for further growth and hardening.

Fig no. 1 Explant Collection

Fig no.2 Inoculation

Fig no.3 Shoot initiation

Fig no.4 Rooting

Fig no.5 Cultured Plant

Fig no.6 Hardening

Conclusion

Micropropagation of neem (*Azadirachta indica)* using nodal segments is a valuable biotechnological method for efficient and large-scale propagation. Unlike traditional seed propagation, which faces challenges like low germination and genetic variability, micropropagation ensures the rapid production of genetically uniform, healthy plants. Nodal segments, which contain one or more plant nodes, are cultured in vitro to regenerate shoots and roots under controlled conditions. To successfully carry out large-scale clonal propagation of neem, it is crucial to develop a reliable protocol that ensures low contamination, high shoot multiplication, and strong plant establishment. While nodal explants were able to produce axillary shoots, their use was limited due to internal fungal and bacterial infections during culture initiation, low multiplication rates, poor rooting, and issues related to the juvenile nature of the material. However, challenges remain in optimizing protocols for large-scale production and managing the costs of media and growth regulators. Despite these hurdles, the method holds significant potential for the sustainable propagation of neem, offering benefits for both ecological restoration and the commercial production of neem-based products. With continued research, micropropagation of neem can become even more efficient and widely adopted.

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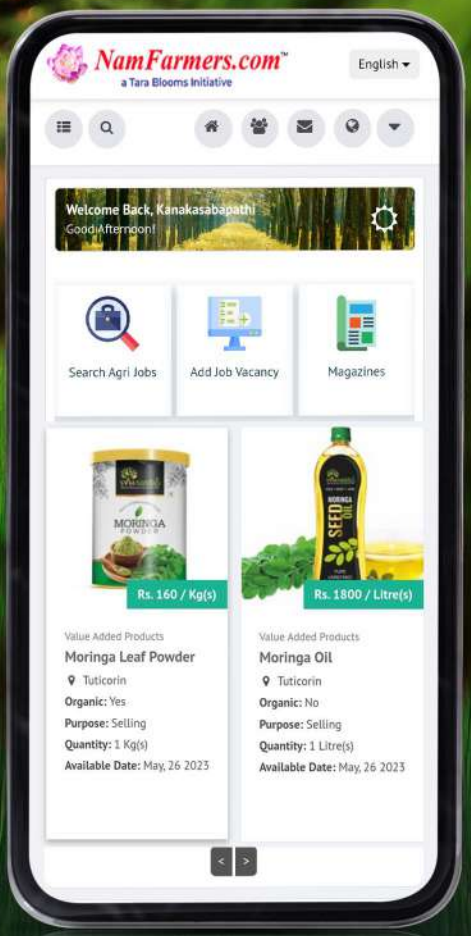

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