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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. 07 – July 2025"** with immense pleasure our team is privileged to dedicate this issue to **Agricultural education Youths**. **World Youth Skills Day** is celebrated on 15th July every year to raise awareness about the importance of technical, vocational education & training and the development of other skills relevant to both local and global economies. In Tamil Nadu, July 15th is celebrated as **Educational Development Day**. This day commemorates the birth anniversary of the former **Chief Minister, K. Kamaraj**, and recognizes his significant contributions to education.

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
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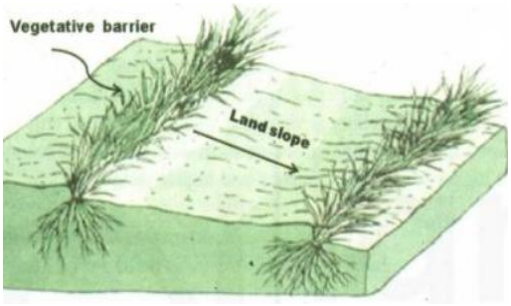
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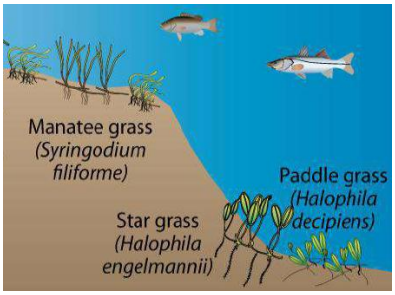
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GENETIC GOLD: HOW SEED SCIENCE IS FEEDING THE WORLD?

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Abstract

Seed science is at the forefront of a quiet revolution in global agriculture. As the world grapples with increasing food demand, erratic climate conditions, and diminishing natural resources, improved seed varieties have become essential for sustainable food production. From drought-resistant grains to nutrient-enriched staples, the latest innovations in seed technology are enabling farmers to grow more resilient and productive crops. This article explores how advances in genetic breeding, biotechnology, and biofortification are transforming seeds into powerful tools for climate adaptation, nutritional enhancement, and rural development. With seed science driving progress at the root level, agriculture is better equipped to feed a growing population and meet the complex challenges of the 21st century.

Introduction

At the heart of every harvest lies something deceptively small, yet unimaginably powerful—the seed. These unassuming capsules of life are the quiet engines behind every loaf of bread, every spoon of rice, and every glass of milk. As the world stands at the crossroads of climate crisis, food insecurity, and population growth, a new era of seed science is emerging—one that promises to reshape agriculture from the roots up. In this age of uncertainty, seeds are no longer just biological starting points. They are becoming instruments of resilience, nutrition, and economic empowerment.

As researchers harness genetics, biotechnology, and cutting-edge breeding techniques, seeds are being transformed into precision tools that can feed the world and sustain the planet.

Seeds: Humanity's First and Most Enduring Innovation

Long before satellites guided tractors or sensors measured soil moisture, early farmers were scientists in their own right. Through careful observation and trial, they selected the strongest plants, saved their seeds, and began the process of domestication that still feeds us today.

Fast forward to the 21st century, and that centuries-old practice has become a high-tech, high-stakes science. Modern seed development combines traditional breeding with powerful tools like molecular markers, genomic sequencing, and gene editing, drastically accelerating the ability to create new and improved varieties.

This shift isn't just a matter of speed—it's a matter of survival. With global temperatures rising, arable land shrinking, and extreme weather events becoming more frequent, the ability to rapidly develop climate-resilient seeds could be the difference between abundance and scarcity for millions.

Resilience Begins at the Seed Level

One of the greatest threats to agriculture today is climate volatility. Drought, heat waves, floods, and shifting rainfall patterns are increasingly disrupting crop cycles. In this unstable environment, seed science is delivering some of the most practical and impactful solutions.

Through precision breeding and gene mapping, scientists are creating crop varieties that can withstand stress conditions—drought-tolerant maize in sub-Saharan Africa, submergence-tolerant rice in Southeast Asia, and salt-resistant barley in coastal regions. These crops are not experimental novelties; they are being planted today by real farmers, on real farms, often with yield improvements of 20%–40% compared to conventional varieties under stress.

In India, for instance, the adoption of flood-tolerant "Swarna Sub1" rice has allowed smallholder farmers in the eastern states to recover harvests even after prolonged submersion. In Kenya and Nigeria, drought-resilient maize hybrids have helped maintain food production during dry spells, safeguarding both household nutrition and local economies. By enhancing a plant's ability to thrive under extreme conditions, seed science is offering a lifeline to farmers on the frontlines of climate change.

Feeding the Body and the Future: Seeds and Nutrition

Agricultural abundance is no longer just about volume—it's about value. Many of the world's most vulnerable communities face a double burden: not only is food sometimes scarce, but the food available often lacks essential nutrients. This is where biofortified seeds come into play.

Through selective breeding and genetic enhancement, researchers are developing staple crops that are naturally fortified with key vitamins and minerals. Golden rice, rich in vitamin A, aims to combat childhood blindness and immune deficiency in Asia. Iron-rich pearl millet is being cultivated in parts of Africa and India to address widespread anemia. Zinc-enriched wheat varieties are now reaching farmers in Pakistan and northern India.

These nutrient-enhanced crops are helping bridge the gap between agriculture and public health, turning every meal into an opportunity for better wellbeing. As part of the global movement toward food systems that nourish rather than just fill, biofortified seeds are quietly transforming diets at the grassroots level.

The Seed Industry: Innovation, Access, and Equity

While the science of seed development has advanced rapidly, questions of equity and access remain pressing. The global seed market, projected to surpass $100 billion in the coming decade, is dominated by a handful of multinational corporations. These companies invest heavily in R&D, producing high-performing hybrids and genetically engineered traits—but the high costs, intellectual property restrictions, and regulatory hurdles can make it difficult for smallholder farmers to benefit.

Moreover, in many low-income regions, informal seed systems still dominate. Farmers rely on saved seeds, local exchanges, and public breeding institutions. Ensuring these communities have access to improved, high-quality seeds is critical—not just for food production, but for economic empowerment.

Efforts are underway to close this gap. Open-source breeding models, farmer-participatory varietal trials, and national seed banks are strengthening local seed systems. In some regions, community seed networks are reviving indigenous varieties that are uniquely suited to local ecosystems, while blending them with modern improvements.

Ultimately, democratizing seed science is key. It's not enough to develop "super seeds" in the lab—they must reach the hands of those who need them most.

Beyond the Field: Seeds as a Strategic Investment

The value of seed innovation extends far beyond the farm. It is tied to global development, environmental sustainability, and economic resilience. Every improved seed represents an opportunity to produce more with less: less water, less land, less chemical input, and less labor. This is especially important in an era where agriculture must become not only more productive but more sustainable.

Governments, NGOs, and development agencies are increasingly recognizing the strategic importance of seed systems. Investments in public breeding programs, regulatory harmonization, and farmer education are vital for scaling up the impact of seed technology.

As the global community works toward the Sustainable Development Goals—particularly zero hunger, climate action, and poverty reduction—seed innovation stands out as a critical, high-leverage intervention.

Conclusion

Seeds are, quite literally, the source of life. They hold within them centuries of evolution, generations of knowledge, and the potential for a more food-secure and climate-resilient future. As science continues to unlock their hidden potential, these tiny biological powerhouses may well be our best hope for feeding a hungry planet. But innovation alone is not enough. For seed science to truly fulfill its promise, we must ensure that its benefits are inclusive, ethical, and accessible to all—especially the farmers who feed the world.

In the end, genetic gold is not just a metaphor. It's a reality rooted in every improved seed, every climate-proof harvest, and every child nourished by a biofortified meal. The seeds of tomorrow are being planted today—and they're growing a better world for all of us.

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INFLUENCE OF TEMPERATURE ON GROWTH AND DEVELOPMENT

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Abstract

Vegetable crops are highly sensitive to both biotic and abiotic stress. Heat and cold stress negatively impact vegetables by disrupting their normal physiological processes, leading to reduced growth, yield and quality. High temperatures can cause dehydration, sunburn and heat stress, while low temperatures can lead to frost damage, slowed metabolism and tissue death. These stresses can affect various stages of development, including germination, vegetative growth and reproduction. This article, gives comprehensive information on effects of heat and cold stress on vegetable crops. This will help us to protect our crop from heat and cold stress.

Introduction

Temperature: The degree of hotness or coldness of a substance is called temperature. It is commonly expressed in degree Celsius or centigrade (C) and degree Fahrenheit (F). Temperature significantly impacts plant growth and development by affecting various physiological processes like photosynthesis, respiration, germination, flowering, and cell division, with each plant species having an optimal temperature range where growth is most efficient; exceeding this range, whether too hot or too cold, can hinder growth and even cause damage to the plant.

Influence Of High Temperature

Extreme temperature above 40 C causes desiccation whereas temperature below 0 C witness chilling and freezing injury in many vegetables. A constantly high temperature endorse

morphoanatomical changes in vegetables which hamper the seed germination, plant growth, flowering, pollen viability, fertilization, fruit setting, fruit size, fruit weight, fruit quality, etc.

INFLUENCE OF LOW TEMPERATURE

Plants suffer low temperature which includes chilling and freezing temperature and the extent of damage varies considerably according to different crops. Vegetables suffer chilling injury with temperature ranges from 0°C-10°C and freezing injury below 0°C which cause significantly damage to crops.

INFLUENCE OF TEMPERATURE ON GROWTH AND DEVELOPMENT

1. GERMINATION

Temperature plays a crucial role in the germination of plants, influencing various physiological processes that are essential for the emergence and development of seedlings. **Enzyme Activity:** Optimal temperatures enhance enzyme activity, promoting the metabolic processes necessary for germination.

Respiration: Temperature influences the rate of respiration, with higher temperatures generally increasing the metabolic activity and energy production required for germination.

Water Uptake: Optimal temperatures facilitate efficient water uptake by the seed, leading to the rehydration of cells and the initiation of metabolic processes.

Gibberellin Synthesis: Warmer temperatures often promote the production of gibberellins, which in turn stimulate the production of enzymes that break down stored reserves in the seed.

2. CELL DIVISION

The rate and efficiency of cell division are influenced by temperature, and various physiological mechanisms are involved in this relationship.

Enzyme Activity: Temperature affects the activity of enzymes involved in the cell cycle, including those responsible for DNA replication, mitosis, and cytokinesis.

Cellular Metabolism: Temperature influences the overall metabolic rate of cells. Cellular metabolism provides the energy and building blocks necessary for cell division.

Protein Synthesis: Proteins, including those that regulate the cell cycle and control checkpoints, are synthesized more rapidly at higher temperatures.

Cell Cycle Regulation: Temperature can affect the duration of each phase of the cell cycle, including the G1, S, G2, and M phases.

3. NUTRIENT ABSORPTION

The uptake of nutrients by plant roots is a crucial aspect of plant nutrition, and temperature affects various mechanisms involved in nutrient absorption

Root Metabolism: Root metabolism influences processes such as ion exchange, nutrient transport, and the conversion of nutrients into forms that can be utilized by the plant.

Water Uptake: Adequate water uptake is essential for maintaining turgor pressure in root cells and creating a favorable environment for nutrient absorption.

Microbial Activity in the Rhizosphere: Warmer temperatures can increase microbial activity, promoting nutrient mineralization and making nutrients more available for plant uptake.

Ion Transport and Membrane Permeability: Changes in membrane permeability, driven by temperature, can influence the uptake of specific ions like nitrate, phosphate, potassium, and others.

4. HORMONAL REGULATION

Plant hormones, also known as phytohormones, are signaling molecules that coordinate growth, development, and responses to environmental stimuli. The synthesis, metabolism, and activity of these hormones are often influenced by temperature.

Auxins: Temperature influences the distribution and transport of auxins within the plant. Higher temperatures generally promote auxin synthesis and transport, affecting processes like tropic responses (e.g., phototropism and gravitropism).

Gibberellins: Temperature affects the synthesis and activity of gibberellins. Warmer temperatures often stimulate the production of gibberellins, influencing plant growth processes.

Cytokinins: Temperature influences the balance between auxins and cytokinins. Warmer temperatures may alter the ratio of these hormones, affecting processes such as shoot and root growth.

Abscisic Acid (ABA): Temperature can influence the synthesis and degradation of ABA. Higher temperatures may lead to increased ABA levels, particularly in response to stress conditions.

Ethylene: Temperature regulates the production of ethylene. For example, higher temperatures often accelerate the ripening process in climacteric fruits by increasing ethylene production.

Jasmonates: Temperature can influence the synthesis of jasmonates, triggering defense mechanisms in response to temperature-induced stress.

Brassinosteroids: Temperature affects the biosynthesis and activity of brassinosteroids, influencing plant growth and development.

5. FLOWERING TIME

Temperature plays a crucial role in regulating the flowering of plants, influencing the timing and success of this essential reproductive process.

Vernalization: Vernalization is particularly important for biennial and winter annual plants, ensuring that they flower during the appropriate season.

Photoperiod Sensitivity: Warmer temperatures may accelerate or delay the response of plants to photoperiodic signals, influencing the transition from vegetative growth to flowering.

Chilling Requirement: This chilling requirement ensures that flowering occurs in response to appropriate temperature conditions, preventing premature flowering during warm periods.

6. FRUIT DEVELOPMENT

Fruit Set: Extreme temperatures, especially during the flowering stage, can adversely affect pollination and fertilization, leading to poor fruit set.

Ripening: Warmer temperatures generally accelerate the ripening process, influencing changes in color, texture, and flavor. However, excessively high temperatures may lead to irregular ripening and affect fruit quality.

7. DORMANCY

Dormancy is a state of reduced metabolic activity and growth that allows plants to survive adverse environmental conditions, especially during periods when external factors are less favorable for growth and development. Temperature influences the onset, maintenance, and release of dormancy in various plant species

Dormancy Release: Warm temperatures during late winter or early spring signal to plants that environmental conditions are becoming favorable for growth. This release from dormancy allows plants to resume active development.

Seed Dormancy: Cold stratification, a process where seeds are exposed to cold and moist conditions, is often used to break dormancy in seeds that have a chilling requirement.

Dormancy Induction: Induction of dormancy is often associated with changes in the levels of plant hormones, such as abscisic acid (ABA).

Heat-Induced Dormancy: This is a protective mechanism that allows plants to conserve water and energy until more favorable conditions return. Heat-induced dormancy is common in regions with hot and dry climates.

CLIMATE RESILIENT TECHNOLOGIES

Management practices for enhancing vegetable production:

- Agronomical adaptation
- Organic Agriculture: Mitigation of Climate Change
- Water management
- Protected cultivation
- Improved pest management
- Use of Heat - and Cold-Tolerant Genotypes

CUCURBITS PRODUCTION IN COLD DESERT

- Commercial production of cucurbits in cold desert of India is now possible through protected cultivation.
- Sarda melon imported in large quantity in the country can be produced in these areas with ease.
- Production of off season (August and September) muskmelon, watermelon, etc. in open fields has also become possible. An early crop of cucurbits like squash and long melon can also be taken in poly houses.

PLASTIC LOW TUNNEL TECHNOLOGY

- Plastic low tunnels provide a cheap and better way for off- season cultivation of vegetable production.
- Low tunnels also offer several advantages like protection of the crop from adverse climate along with crop advancement from 20 to 30 days over their normal season of cultivation.
- Healthy and early nursery raising can be obtained under low tunnels. Technology for cucurbits production has been extended to the farming community successfully.

GRAFTING OF VEGETABLES FOR STRESS MANAGEMENT

- Grafted plants are also able to tolerate low soil temperatures. Solanum lycopersicum x S. habrochaites rootstocks provide tolerance to low soil temperatures (10°C to 13°C) for

their grafted tomato scions, while eggplants can be grafted on wild brinjal (***S. integrifolium***) as rootstocks to overcome low temperatures (18°C to 21°C).

Some varieties of vegetables to mitigate the harmful effect of heat and cold

S.No	crop	varieties	Tolerance
1	Tomato	PusaSadabahar, Pusa Sheetal Pusa Hybrid-1	Tolerant to high and low temperatures
2	Radish	Pusa Chetki	Better root formation under high temperature regime, i.e. April-August
3	Carrot	Pusa Vrishti	Form root at high temperature and high humidity i.e. March-August
4	Early cauliflower	Pusa Meghna	can form curd at high temperature

Physiological disorders of vegetable crops caused by high temperatures

S. No	Crop	Disorder	Aggravating factor
01	Asparagus	High fiber in stalks and spheres	High Temperature
02	Asparagus	Feathering and lateral branch growth	Temperature > 32°C, especially if picking frequency is not increased
03	Bean	High fiber in pods	High temperature
04	Carrot	Low carotene content	Temperatures < 10 °C or > 20 °C
05	Cauliflower	Blindness, buttoning, riceyness	Temperature fluctuations
06	Cauliflower, Broccoli	Hollow strem , leafy heads, no heads, bracting	High temperature
07	Cole crops and lettuce	Tip burn	Drought, combined with high temperatures; high respiration
08	Tomato , pepper, watermelon	Blossom end rot	High temperature , especially if combined with drought and high transpiration.

ALLEVIATION OF COLD STRESS IN VEGETABLE CROPS

Cold stress is responsible for a range of physiological disturbances in chilling-sensitive plants and can cause chilling injury and death of many horticulture plants. Low temperature stress is a harsh constraint, which negatively affects vegetable crops productivity. However, several mechanisms in plants are involved in alleviating cold stress through natural tolerance system. One of the key approach is cold acclimation that helps in stabilizing membranes against freezing injury.

WEATHER TRACKING IN EOSDA CROP MONITORING

- EOSDA Crop Monitoring is an online satellite-based precision agriculture platform for field monitoring created by EOS Data Analytics (EOSDA), a global provider of AI-powered satellite imagery analytics.
- With EOSDA Crop Monitoring, you can access three distinct types of weather information at any time: historical records, current readings, and forecasts. As you add fields to your account, statistics like these will be collected for each of them.

To protect your crops from the negative effects of extreme temperatures, you can do the following:

- keep an eye on the current temperatures and other meteorological parameters, including precipitation, wind, humidity, and clouds, as they are updated daily; research past weather records (information is accessible from 1979 onwards) to identify potentially dangerous periods;
- consult a reliable 14-day forecast and plan ahead to protect your plants from cold and heat stress.

Conclusion

In conclusion, heat and cold stress significantly impact vegetable crop productivity, quality and yields. Rising temperature and unpredictable weather patterns due to climatic change exacerbate these stresses, threatening global food security. Understanding the effects of heat and cold stresses on vegetable crop is crucial for developing effective mitigation strategies. Helps us to implement stress management strategies, such as mulching, shading and wind protection, to develop and promote climate resilient agricultural practice, and to support research and development of stress tolerant crop varieties.

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MEDIA FOR PROPAGATING NURSERY PLANTS

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Abstract

Growing media for greenhouse container production consist of various organic (e.g., peat, bark, coir) and inorganic (e.g., perlite, vermiculite, sand) components, each contributing to essential properties like aeration, water retention, and nutrient availability. Field soils are typically unsuitable due to poor drainage and disease risks. Proper media selection supports healthy root development, enhances plant growth, and reduces pest and disease incidence. Materials like sphagnum peat, coir, and pine bark are widely used for their stability and efficiency. Effective media management tailored to plant needs and conditions is key to successful nursery propagation.

Introduction

Growing media for use in container production in greenhouses contain a variety of organic and inorganic ingredients. Organic ingredients include peat moss, bark, coconut coir, rice hulls, etc. Inorganic components include perlite, pumice, vermiculite, sand, hydrogel, etc. Field soils are generally unsatisfactory for producing plants in containers because soils do not provide the aeration, drainage and water holding capacity required and they need to be pasteurized or fumigated to prevent diseases and weeds. Except for organic growers, there are relatively few

commercial operations that directly use soil. Some of these ingredients can be used alone to grow crops, but more often, growing media are made with different portions of various materials, each contributing to the chemical and physical properties of the final product.

Organic Media Components

Peat: Peat is a main component of most soilless substrate mixes used today. Peat consists of the remains of aquatic, marsh, bog, or swamp vegetation that has been preserved under water in a partially decomposed state. Composition of different peat deposits varies widely, depending upon the vegetation from which it originated, state of decomposition, mineral content, and degree of acidity.

Sphagnum Peat Moss: Sphagnum peat moss remains the premier component of greenhouse media because of its high-water holding capacity, adequate air space, high cation exchange capacity, and resistance to decay. Sphagnum peat moss is light brown in color (dark brown when wet), and the sphagnum plant structure is still visible. It has superior properties of stability over time, light weight, and high water and nutrient-holding capacities. Sphagnum peat moss is the most acid of the peats, with a pH level of 3.0 to 4.0, and requires 14 to 35 pounds of finely ground limestone (dolomite) per cubic yard (8 to 20 kg/m3) to bring the pH up to the level that is best for most crops. In areas with alkaline water, the lower rate may be suitable. Due to its naturally low pH, peat moss is free of active pathogenic diseases.

Shredded Bark: Shredded or pulverized softwood bark from redwood, cedar, fir, pine, hemlock, or various hardwood bark species, such as oaks and maples, can be used as an organic component in growing mixes and are frequently substituted for peat moss at a lower cost. Shredded bark functions to improve aeration and reduce the cost of substrate. Bark variability stems from the species and age of tree, method of bark removal and degree of decomposition. Based on the level of decomposition, bark could be categorized as fresh, aged, or composted. Aging is a cheaper process, but aged bark has less humus and a greater nitrogen drawdown in the container than composted bark.

Pine Bark: Pine bark is preferred over hardwood bark since it resists decomposition and contains fewer leachable organic acids. Pine bark is usually stripped from the trees, milled and then screened into various sizes. A good potting medium usually consists of 70 to 80 percent (by volume) of the particles in the 1/42 to 3/8-inch (0.6 to 9.5 mm) range with the remaining

particles less than 1/42 inch. If pine bark is too coarse, water retention will not be adequate for plant growth.

Hardwood Bark: Hardwood bark is a commonly used and is an excellent substrate ingredient. Hardwood bark should be mechanically processed to small particles, which will pass through a ½-inch (12.7 mm) mesh screen, with 10 percent of the particles larger than 1/8-inch (3.2 mm) diameter and 35 percent less than 1/32-inch (0.8 mm) diameter.

Coir: The substrate coir is derived from the husks of coconut fruit. After most of the fibers are removed, the remaining coir, or coir dust, is marketed for substrate. Chemical and physical properties of the coir are variable, depending largely on the amount of fiber remaining in the material. Its physical and chemical properties are probably closer to peat moss than any other existing substrate material. Coir generally has a higher pH (4.9 to 6.8) than sphagnum peat moss, so it requires less limestone to adjust substrate pH. If not properly processed, the electrical conductivity (EC) of coir-based substrates can exceed the recommended levels for container-grown plants.

Sawdust: Sawdust has characteristics that make it desirable for use in a growing mix. It has a bulk density slightly less than sphagnum peat moss, has similar water retention but greater air space after drainage than pine bark.

Rice Hulls: Rice hulls used in growing media are parboiled and then dried before use. The primary function of rice hulls is that of drainage and aeration. Large particle sizes of whole parboiled fresh rice hulls can increase the drainage and air-filled pore space in peat-based substrates without causing significant nitrogen immobilization. Rice hulls provide a less expensive substitute for perlite and add a higher level of aeration than gained by an equal amount of perlite in the substrate.

Soil: Soil is used as a part of a medium by some greenhouses. However, topsoil supply, uniformity, and quality are difficult to maintain and soil must be pasteurized or fumigated. Pasteurization of some soils at high temperatures creates additional problems such as manganese toxicity and an imbalance between ammonifying and nitrifying bacteria. The high bulk density of a soil medium increases handling labor and cost of shipping plants. Typically, soil-based root media is amended so that it is relatively lightweight.

Animal Manure Composts: Non-composted animal manure is rarely used in greenhouse production today. Although manures do contain most essential nutrients for plant growth, the concentration of elements varies considerably with the animal, mulching material used (straw, etc.), the technique of manure collection and storage, and manure age. In addition, fresh manures are not pleasant to handle, considering the odor and the high-water content. Some potential dangers in using raw manure include: soluble salt damage from high nutrient content, ammonia damage to roots and foliage, and weed seeds, insects, pathogens and nematodes contained in non-pasteurized or non-fumigated manures.





Inorganic media components:

Vermiculite: Vermiculite, an aluminum-iron-magnesium silicate, is a mica-like mineral that provides spaces for air and water. When expanded, vermiculite is very light in weight, neutral in reaction with good buffering properties, and insoluble in water. Vermiculite has a relatively high cation-exchange capacity and thus can hold nutrients in reserve for later release. It contains magnesium and potassium, but supplementary amounts are needed from other fertilizer sources. The pH of most of the vermiculite used in horticulture falls within a range of 6.0 to 8.9. One of the major shortcomings of vermiculite is its poor physical stability after wetting. Particles which have been mixed, wetted and compressed do not recover physically. Compression of moist vermiculite causes the expanded particle to collapse and frequently slip apart.

Perlite: Perlite is a volcanic rock that is crushed and heated rapidly to a high temperature forming a white, light-weight aggregate with high pore space. Perlite is utilized extensively for its light weight, physical stability and ability to improve the drainage or aeration. The water-

holding capacity of perlite is 3 to 4 times its own. It is chemically inert with almost no CEC or nutrients, and a neutral pH.

Calcined Clay: Aggregates of clay particles are heated to high temperatures (calcined) to form hardened particles, which make them desirable as potting substrates. Calcined clays are essentially indestructible particles, which provide non-capillary pore space to a mix due to the large spaces created between particles and hold water internally within their open-pore particle structure.

Sand: Sand is the most common addition to growing media. The composition of sand varies widely. Sands derived from calcareous sources (such as coral or limestone) are high in calcium carbonate (CaCO3); however, can have dangerously high pH values. Some plants grown in the greenhouse may be adapted to local calcareous soil conditions and may not suffer from the increased pH if the sand is used sparingly. Deep-mined, white mountain sands are mainly silica. These white sands are called sharp or builders' sands because the sand particles have flat sides.

Rockwool: Rockwool is manufactured from a mineral called basalt through a heating and fiber extrusion process. Horticultural-grade rock wool is formulated to a prescribed higher density to provide the air- and water-holding requirements of plants. A distinct characteristic of rock wool is its high air-holding capacity even when fully saturated. Rockwool contains only a very small amounts of nutrients such as calcium, magnesium, sulfur, iron, copper, and zinc. Nutrient availability is dictated by the nutrient solution applied. The pH of rock wool is between 7.0 and 8.5 (often 8.0) but is not buffered. Mixing it with an acid component, such as pine bark or peat moss, will immediately lower the pH level. The pH level of the rock wool will adjust to the nutrient-solution pH level after one application.

Benefits of Propagation media:

1. An optimum rooting environment for physical stability.
2. Storage of air for the roots
3. Water absorption and retention and make availability to the plant when needed.
4. Supply of nutrients for the roots.
5. Healthy growth of plants.
6. Reduced chances of Disease and pest attack.

Conclusion

The choice and management of propagating media play a foundational role in the success of nursery operations, influencing plant quality, propagation speed, and overall productivity. Ongoing evaluation and adjustment based on plant species and local environmental conditions are essential for optimal results.

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AGRI-STARTUPS IN RURAL INDIA: HOW EXTENSION IS NURTURING NEW-AGE FARMERS

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Abstract

India's rural agrarian landscape is undergoing a transformation, driven by the emergence of agri-startups led by youth and powered by innovation. These enterprises address challenges in productivity, climate adaptation, and market access through tech-enabled solutions. Agricultural extension, once a channel for technology transfer, is now a critical enabler of agri-entrepreneurship. It nurtures startups by offering skill development, incubation, market linkages, and mentorship. Platforms like KVKs and AgHub in Telangana exemplify this shift. Agri-startups such as Marut Drones, Our Food, and Kalgudi highlight the synergy between innovation and extension support. Real-life stories, like that of a biopesticide entrepreneur from Karimnagar, reflect the ground impact. Telangana's proactive policies and strong institutional ecosystem make it a model state. The convergence of startups and extension is paving the way for resilient, youth-driven agriculture. This marks a strategic evolution towards a self-reliant and inclusive rural economy.

Introduction

India's agricultural sector has traditionally been a lifeline for the rural population, but it has long faced challenges — from low productivity and climate change to market inefficiencies and poor price realization. In recent years, however, a new generation of agri-preneurs has emerged, using innovation and technology to tackle these issues. These agri-startups are not just

urban tech interventions but increasingly rural-based, youth-led enterprises that aim to bring transformation at the grassroots.

Amidst this entrepreneurial wave, agricultural extension systems — once associated primarily with crop advisory — are evolving into facilitators, mentors, and incubators of innovation. This synergy between extension services and agri-startups holds the key to shaping a more sustainable, profitable, and inclusive farming future.

Keywords: Startups, Policies and Platforms

What are Agri-Startups?

Agri-startups are enterprises that develop innovative, scalable, and market-driven solutions to problems in the agriculture and allied sectors. They span a wide range of activities such as:

- Precision agriculture using drones, IoT sensors, and satellite imagery
- Digital platforms for market linkages, weather forecasting, and advisory
- On-farm processing units and cold chain logistics
- AI-based soil and crop health diagnostics
- Value-added product enterprises in millets, organic foods, dairy, etc.

Over 2,000 plus agri-startups have emerged across India in the last decade. These startups are increasingly reaching rural regions, creating job opportunities for educated youth, women, and progressive farmers.

Extension's New Role in the Startup Ecosystem

Traditional vs. Modern Extension

Earlier, extension services focused on "technology transfer" — distributing recommended practices, seed varieties, and pest control methods from research stations to farmers. However, the current landscape demands that extension becomes more dynamic, entrepreneurial, and participatory.

Today, agricultural extension in India is also about:

- Facilitating innovations at the grassroots
- Building entrepreneurial capacity
- Linking agri-startups with farmer networks
- Handholding rural youth in startup incubation

This transformation is evident in both public extension systems like Krishi Vigyan Kendras (KVKs), State Departments of Agriculture, and SAUs, as well as NGO and private sector initiatives.

How Extension Nurtures Agri-Startups

1. Skill Development & Entrepreneurial Training

Many agri-startups begin with a simple idea by a rural youth or farmer. Extension systems help convert this idea into a viable business through:

- Entrepreneurship Development Programs (EDPs) on areas like input manufacturing, vermicomposting, nursery raising, or food processing.
- Training on business planning, financial literacy, and market linkages.

For example, KVK Jammikunta (Karimnagar) and KVK Malyal (Mahabubabad) have trained hundreds of youth in mushroom production, millet value addition, and agri-input enterprises.

2. Incubation Support

Extension systems are increasingly partnering with Agri-Business Incubators that provide:

- Infrastructure and lab access
- Legal and compliance assistance
- Seed funding and venture capital connections
- Mentorship from researchers and extension officers

AgHub at PJTAU, Hyderabad is a prime example. It has incubated startups in drone spraying, smart irrigation, agri-fintech, and organic inputs. Extension professionals here act as technical mentors and facilitators of field validation.

3. Field Testing & Farmer Outreach

Extension systems help agri-startups test their innovations in real farm conditions. They also provide linkages to farmer networks, making it easier for startups to reach their target users. For instance:

- In Warangal and Nalgonda, extension workers helped Marut Drones test UAVs for spraying and pest monitoring on cotton and paddy fields.
- Farm advisory apps like Kalgudi and Krishikan benefited from KVK support in gathering farmer feedback and improving user-friendliness.

4. Connecting to Government Schemes

Many startups lack awareness of the schemes available to them. Extension systems help bridge this gap by providing:

- Information about funding opportunities (e.g., RKVY-RAFTAAR, PM FME, Startup India Seed Fund, etc.)
- Support in applying for loans, subsidies, and licensing.
- Assistance in meeting quality and compliance standards (like FSSAI, organic certification, etc.)

Telangana: A Leading Example

Telangana has emerged as a pioneering state in agri-startup promotion, due to:

- Progressive policies supporting innovation and startups
- Strong ecosystem of research institutions, incubation centers, and public-private partnerships
- Entrepreneurial youth from rural and semi-urban areas actively engaging with extension services

Notable Agri-Startups from Telangana:

Startup Name	Area of Innovation	Link to Extension
Marut Drones	Drone spraying and crop health	Piloted with support from KVKs in Warangal
Our Food	Rural food processing units	Partnered with Krishi Vigyan Kendras
Kalgudi	Digital agri marketplace	Connected with farmers through extension agents
Eruvaka Technologies	IoT for aquaculture	Validated in collaboration with ICAR and extension researchers

Real-Life Success Story

Suresh Reddy, a 28-year-old agri-graduate from Karimnagar, started a small-scale unit for neem oil-based biopesticides after training from KVK Jammikunta. With mentorship from AgHub, he developed branded products and now supplies to 150+ farmers locally.

“Without the guidance of the extension team, I wouldn’t have even known how to register my business,” he says.

Future Directions

To strengthen this synergy further, the following steps are essential:

1. Entrepreneurship-focused curricula in SAUs and polytechnic institutes
2. Integration of extension professionals as startup mentors
3. Inclusion of incubation and startup exposure in farmer field schools (FFS)
4. Strengthening district-level startup extension clusters

Conclusion

The fusion of agri-startups and extension systems is not just a trend — it is a strategic shift in Indian agriculture. With the vision of Atma Nirbhar Bharat and Doubling Farmers' Income, the role of startups in achieving economic resilience for farmers is more crucial than ever. Extension is no longer a one-way transmitter of knowledge; it is now a platform for co-creation, innovation, and entrepreneurship. Telangana's experience shows that with the right support system, rural youth can become not just job seekers but job creators in agriculture.

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HARVEST HANDLING AND PACKAGING OF FRUITS

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Abstract

Fruit production is crucial for global agriculture and nutrition, but poor postharvest practices can cause 30 - 50% losses, especially in developing countries. This article outlines key stages in postharvest handling harvesting at the right maturity, careful handling, pre cooling, cleaning, sorting, and smart packaging to preserve fruit quality. Effective storage, transport, and ethylene management further reduce spoilage. Innovations like smart packaging, edible coatings, and IoT based cold chains enhance sustainability. Overall, efficient postharvest systems are vital for reducing waste and delivering high-quality produce to consumers.

Introduction

Fruit production plays a vital role in agricultural economies and nutrition worldwide. However, the value of fruit crops is heavily dependent on how they are handled and packaged after harvest. Poor postharvest practices can lead to up to **30–50% losses** in fruits, particularly in developing countries. This article explores the elaborate process of **harvest handling and packaging**, aiming to minimize postharvest losses, preserve quality, and ensure fruits reach consumers in optimal condition.

1. HARVESTING: THE FIRST CRITICAL STEP

Harvesting is more than just picking fruit; it marks the transition from growth to preservation. **Harvest timing, method, and care** directly affect fruit quality and longevity.

1.1. HARVEST MATURITY

Fruits must be harvested at the correct stage of physiological and commercial maturity.

- **Physiological maturity** refers to the stage when a fruit has completed its development and can ripen normally off the plant.

Type of Fruit	Harvested When…
Mango, Banana	Mature but green (climacteric – can ripen after harvest)
Grapes, Citrus	Fully ripe on the plant (non-climacteric – don't ripen further)

- **Commercial maturity** is when the fruit has reached the size, color, and quality required by the market.

Harvest indices include skin color, days from flowering, firmness, sugar content (°Brix), and size.

1.2. HARVESTING TOOLS AND TECHNIQUES

- **Manual Harvesting:** Most fruits (e.g., apples, oranges, strawberries) are hand-picked to minimize damage.
- **Mechanical Harvesters:** Used for some fruits like olives or berries, where precision is less critical.

PROPER TRAINING IS ESSENTIAL:

- Use clean, sanitized tools.
- Avoid pulling or dropping fruits.
- Handle fruits gently to avoid internal bruising, even if the skin looks intact.

2. POSTHARVEST HANDLING

Once harvested, fruits continue to **respire**, lose moisture, and can undergo **senescence** (aging) unless steps are taken to preserve them.

2.1. FIELD HEAT REMOVAL (PRE-COOLING)

Removing **field heat** immediately slows respiration and delays spoilage. Methods include:

- **Forced-air cooling:** Cold air is pulled through stacked boxes.
- **Hydrocooling:** Cold water immerses or showers the fruits.
- **Vacuum cooling:** Rapidly lowers pressure to induce evaporative cooling.

Each method is chosen based on fruit type and sensitivity.

2.2. CLEANING AND DISINFECTION

Fruits are often washed to remove:

- **Soil and dust**
- **Pesticide residues**
- **Microbial contaminants**

Water used must be clean and chlorinated (usually 100–150 ppm chlorine), or treated with food-safe alternatives like peracetic acid or ozone. A **fungicide dip** may be applied to reduce rot during storage.

2.3. SORTING AND GRADING

Fruits are sorted based on:

- Size
- Colour
- Ripeness
- External and internal defects (e.g., bruises, cuts, disease symptoms)

Grading ensures uniform quality and helps determine market price. Advanced systems use **optical sensors and AI** for automated sorting.

3. PACKAGING: PROTECTION AND PRESENTATION

Packaging serves both **protective** and **marketing** functions.

3.1. PACKAGING MATERIALS

Ideal packaging should:

- Be **lightweight yet strong**.
- Allow **ventilation** to control humidity and ethylene gas.
- Be **non-toxic** and compliant with food safety standards.

COMMON PACKAGING TYPES:

- **Corrugated fiberboard boxes**: Widely used; customizable sizes.
- **Plastic crates or bins**: Reusable and durable.
- **Trays with molded inserts**: Used for delicate fruits like apples or peaches.

- **Modified Atmosphere Packaging (MAP)**: Extends shelf life by altering oxygen and CO_2 levels inside the package.
- **Biodegradable alternatives**: Banana leaf trays, pulp-based containers, and compostable films are emerging as eco-friendly options.

3.2. PACKAGING DESIGN AND LABELING

Design elements that enhance quality preservation:

- Internal padding to prevent movement and bruising.
- Ventilation holes to regulate temperature and humidity.
- Stack ability for transport.



LABELS TYPICALLY INCLUDE:

- Variety
- Grade
- Weight
- Country of origin
- Date of packing
- QR codes for traceability

4. STORAGE AND TRANSPORTATION

Even after packaging, fruits need proper **storage and transport** conditions to retain their freshness.

4.1. TEMPERATURE AND HUMIDITY MANAGEMENT

Each fruit has a specific **optimal storage temperature** and **relative humidity (RH)**.

Fruit	Ideal Temp (°C)	RH (%)
Apples	0–4	90–95
Bananas	13–14	90–95
Strawberries	0	90–95
Citrus	5–9	85–90

STORING AT INCORRECT TEMPERATURES CAN CAUSE:

- **Chilling injury** (in tropical fruits)

- **Decay and mold growth** (in warm conditions)

4.2. ETHYLENE MANAGEMENT

Ethylene is a natural ripening hormone produced by fruits like bananas, tomatoes, and apples.

- **Sensitive fruits** (e.g., lettuce, grapes) should be stored separately.
- Use of **ethylene scrubbers** or **absorbers** can slow ripening in mixed loads.

4.3. TRANSPORT LOGISTICS

Refrigerated vehicles ("reefers") and **cold chain management** are critical. Even minor temperature fluctuations can shorten shelf life or degrade quality.

5. INNOVATIONS AND SUSTAINABILITY IN PACKAGING

Recent trends in postharvest handling focus on:

- **Smart packaging**: Labels that change color based on freshness or temperature.
- **Edible coatings**: Made from natural polymers (e.g., chitosan, aloe vera) to reduce moisture loss and microbial growth.
- **IoT - based cold chain monitoring**: Real-time tracking of temperature and humidity during storage and transport.





Conclusion

Efficient harvest handling and packaging practices are essential to preserve the quality, safety, and marketability of fruits. From choosing the right harvest time to using temperature-controlled transport, every step matters in minimizing postharvest losses. With increasing demand for high-quality and sustainably packaged produce, producers must continually adapt by adopting modern technologies, improving training, and using environmentally friendly materials. Investing in proper postharvest practices is not just about reducing waste—it's about delivering better value to both farmers and consumers.

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FARMING SYSTEMS AND SUSTAINABLE RESOURCE MANAGEMENT

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Introduction

The terms 'farming systems' and 'mixed farming' are used interchangeably. However, there are some subtle differences between these two. Mixed farming is defined as a system of farming on a particular farm which includes crop production, raising livestock, poultry, fisheries, bee keeping etc., to sustain and satisfy as many needs of the farmer as possible. Subsistence is important objective of mixed farming while higher profitability without altering ecological balance is important in farming systems. Different scientists have defined a farming system differently. However, many definitions, in general, convey the same meaning that it is strategy to achieve profitable and sustained agricultural production to meet the diversified needs of farming community through efficient use of farm resources without degrading the natural resource base and environmental quality. Relatively recent definitions include: Farming system is a resource management strategy to achieve economic and sustained agricultural production to meet diverse requirements of farm livelihood while preserving resource base and maintaining a high level of environment quality.

Farming system is a set of agro economic activities that are interrelated and interact with themselves in a particular agrarian setting. It is a mix of farm enterprises to which farm families allocate its resources in order to efficiently utilize the existing enterprises for increasing the productivity and profitability of the farm. These farm enterprises are crop, livestock, aquaculture, agro forestry and agri-horticulture. Farming system is a mix of farm enterprises such as crop, livestock, aquaculture, agro forestry and fruit crops to which farm family allocates its resources

in order to efficiently manage the existing environment for the attainment of the family goal. Farming system represents an appropriate combination of farm enterprises (cropping systems horticulture, livestock, fishery, forestry, poultry) and the means available to the farmer to raise them for profitability. It interacts adequately with environment without dislocating the ecological and socioeconomic balance on one hand and attempts to meet the national goals on the other.

Farming systems approach:

Farming is very complex system with many growth factors involved in it. The farming system enterprises like cropping system, dairying, piggery, poultry, fishery, bee keeping etc. are interrelated. The end products and wastes of one enterprise are used as inputs in others. The wastes of dairying like dung, urine, refuse etc., are used for the preparation of farmyard manure which is an input in cropping systems. The straw obtained from the crops is used as fodder for cattle. Cattle are used for different field operations for growing crops. Thus different enterprises of farming systems are highly interrelated. Besides the interaction of crops, animals, weeds, insects, fungi, bacteria etc. with each other, soil, input levels (seed, fertilizers, chemicals, irrigation etc) and climatic factors (rainfall, temperature, radiation, winds etc.) also interact with them and among themselves.

When we study intensive cultivation as an independent factor, we would certainly lose information about its effects on physico-chemical properties of soil, inputs and other management practices. Therefore, all factors should be studied as a whole so that effect of one factor on another could be evaluated and conclusions drawn on the validity of whole system for the long run. In agro-ecosystem, much more is removed in the form of products, grains or straw etc. and seldom returned to the system leading to imbalances. The various functional units, in agro ecosystems are crops, livestock poultry, machinery, land, processing, investment, marketing facilities etc. All these interact with each other and there is a combined use of input supplies which are received from the environment to satisfy the farm system (agro-ecosystem) as a whole and many other subsystems like soil micro-organisms which is a sub-system of soil and soil is further a subsystem of crop producing system.

Further the crop producing system is a subsystem of farm-system. Some of the farm related subsystems are social, biological and mechanical systems depending upon their environments. These subsystems play an important role in adopting various strategies at the farm and in selection of enterprise for the farm. The farm with agro-ecosystem is, therefore, a man-

biological-machine system. Obviously, it is a very complex system, may be more than an individual plant or soil system. For a systematic planning, it becomes imperative that all related subsystems function in complete harmony with each other for getting high output per unit area per unit time. Neglecting any subsystem may lead to harmful effects on total agro-ecosystem. Therefore, it is important to consider farming as a system. It would be beneficial to group the farms of similar structures. Then each can be expected to produce similar production function e.g. grazing systems and arable systems-intensive farming like rice-wheat cropping system. In arable farming, if there are two farms which have independent subsystems have to be examined separately for improvement and future planning.

Integrated farming systems: An integrated Farming System (IFS) is also defined as a biologically integrated farming system that integrates natural resources and regulation mechanisms into farming activities to achieve maximum replacement of off-farm inputs, secures sustainable production of high-quality food and other products through ecologically preferred technologies, sustains farm income, eliminates or reduces sources of present environment pollutions generated by agriculture and sustains the multiple functions of agriculture. Integrated Farming System 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.

- Efficient recycling of farm and animal wastes.
- Minimizing the nutrient losses
- Maximizing nutrient use efficiency
- Adoption of efficient cropping systems and crop rotations
- The complementary combination of farm enterprises.
- Generally, farmers take more than one enterprise on their farms.
- The main objective of farming is to get maximum profit with minimum expenditure by combining enterprises.
- The combination of enterprises on a farm is influenced by the relationship that exists between the enterprises.
- To identify the existing farming systems in a specific area and asset their relative viability.

- To formulate farming system model involving main and allied enterprises for the different farming systems.
- To ensure optional utilization and conservation of available resources and effective recycling of farm residue within the system.
- To maintain a sustainable production system without damaging resources based on the environmental system.
- To raise the overall profitability of farm households by complementing main allied enterprises with each other, etc.

Component of IFS

- Crop production
- Dairy farming
- Ploultry farming
- Sheep and goat farming
- Aquaculture (Fish farming)
- Duck farming
- Sericulture
- Mushroom cultivation
- Bee keeping

Sustainable agriculture is a farming approach designed to meet current food needs while preserving the environment for future generations. It focuses on balancing three key goals:

- Environmental Health: Sustainable agriculture aims to reduce negative impacts on the environment. This includes conserving water, improving soil health, and reducing pollution from pesticides and fertilizers. Techniques like crop rotation, organic farming, and reduced tillage are commonly used.
- Economic Viability: It ensures that farming practices are economically sustainable for farmers. This means creating methods that are cost-effective and provide a fair income, while also promoting long-term productivity and resilience.
- Social and Community Well-being: Sustainable agriculture supports fair labor practices and contributes to the health and well-being of farming communities. It often involves ensuring that workers are treated fairly and that local communities benefit from agricultural activities.

Overall, sustainable agriculture seeks to create a farming system that is environmentally friendly, economically feasible, and socially responsible.

Sustainable Resource Management: Sustainable resource management means managing resources with the future in mind. Sustainable resource management can be defined as the application of sustainable practices by managing resources in a way that will benefit current and future generations. Resource management plays a critical role in sustainability by ensuring that resources are utilized in a way that meets current needs without compromising the ability of future generations to meet their own needs. By optimizing the use of resources, such as materials, energy, and human capital, and by minimizing waste and environmental impact, resource management practices can contribute to the long-term viability and success of both organizations and broader ecosystems.

One way that resource management contributes to sustainability is through the efficient use of materials and energy. By implementing practices such as reducing, reusing, and recycling, organizations can minimize waste and lower their consumption of raw materials. For instance, in manufacturing, adopting lean principles can lead to more efficient production processes that use fewer materials and produce less waste. In energy management, implementing renewable energy sources and improving energy efficiency can significantly reduce an organization's carbon footprint. These practices not only have environmental benefits but can also result in cost savings for the organization.

Another important aspect of resource management for sustainability is the social dimension, which includes human resources and community engagement. Ensuring fair labour practices, promoting employee well-being, and engaging with local communities are all important for building a sustainable organization. Moreover, sustainable resource management can also encompass making strategic decisions that align with sustainable goals, such as investing in sustainable technologies or engaging in partnerships for sustainable development. By integrating sustainability into resource management practices, organizations can achieve a balance between economic efficiency, environmental stewardship, and social responsibility, contributing to the long-term well-being of both the organization and the planet.

Resource Management for Sustainable Agriculture: Soil and water are two naturally available resources need to be managed efficiently in dry land agriculture. Under given ecological limitation; it is the rainfall variation that causes fluctuation in productivity from year

to year. The following technologies may be followed for resource management. • Effective utilization of stored soil moisture is important and hence crops and varieties having high moisture use efficiency (MUE) need to be used. • Crop planning as per length of cropping season: Select the crop of proper duration to match the length of growing season for stabilizing in crop production.

Conclusion

Soil and water are two naturally available resources need to be managed efficiently in dry land agriculture. Under given ecological limitation, it is the rainfall variation that causes fluctuation in productivity from year to year. The technologies which may be followed for resource management are viz. Effective utilization of stored soil moisture is important and hence crops and varieties having high moisture use efficiency (MUE) need to be used and crop planning as per length of cropping season: Select the crop of proper duration to match the length of growing season for stabilizing in crop production. Common sustainable agriculture practices include ensuring crop diversity, conserving soil and water and using Earth-friendly pest management. Smart farming, the adoption of advanced technologies and data-driven farm operations, is core to the concept of sustainable agriculture.

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CONSUMPTION OF ORGANIC WASTE IN THE PRODUCTION OF BIOFERTILIZER AND ITS QUANTITATIVE ANALYSIS ON *SPINACIA OLERACEA*

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Abstract

The horticulture/ agriculture is a most significant resource area of Indian economy. It contributes to evolution, engagement and overall economy of India. The Indian Government has been trying to promote the use of biofertilizer by providing incentives to the agriculturalist. These inputs have a multiple beneficial impact on the soil. Biofertilizer increases the soil fertility naturally and does not affect the soil like chemical fertilizers. The comparative effect of Biofertilizer on the growth and yield of Spinach (*Spinacia oleracea*) was studied. The seeds of Spinach were treated with biofertilizer and their result was recorded after intervals. The proves that plants treated with Liquid Organic Biofertilizer showed exceptional results in the morphological parameters as compared to controlled plants. The result showed that the plant enactment with respect to biomass components such as mean number of leaves, and plant height and root length were expressively influenced by used biofertilizer. The total plant biomass was found to be higher with application of biofertilizer, DAP and control as compared to combination of aforesaid biofertilizer. Similar trend was noticed with respect to plant of leaves, root length and total fresh weight which were found to be significantly higher 21.33/ plant, 16.28 cm/plant and 102.55 gm/ plant respectively. Biofertilizer has increasing level of growth comprised other treatments. So, it can be concluded that biofertilizer can be best substitute for chemical fertilizer, which has proven positive effects on various crops with environmental sustainability.

Keywords: *Bos indicus*, DAP, *Spinacia oleracea* and Environmental sustainability.

1. Introduction

Accumulative population of the world has doubled the food demands and inundated the

available land sources (Hussain *et al.*, 2011). The need of increased food production in most developing countries becomes an ultimate goal, to meet the dramatic expansion of their population (El-Shaikh KAA *et al.*, 2009). The major vegetables crops are the most important one by cultivation and consumption. The nutritional content of vegetables varies considerably as they contain a great variety of phytochemicals and antioxidant properties. Generally, vegetables are cultivated in all part of the world by using different inputs like chemical fertilizers, pesticides, organic fertilizers, Biofertilizer and bio-pesticides, etc.

In recent days, the use of different organic fertilizers, Biofertilizer and bio-pesticides are being recommended not only to minimize the use of hazardous chemical inputs but also for sustainable crop production particularly in vegetables cultivation (Murungi *et al.*, 2018). Biofertilizer help the better Nitrogen (N) fixation in plants or improving the nutrient availability in the soil. In early 1900's, Hellriegal and Wilfarth demonstrated clearly that fixation of atmospheric nitrogen takes place in legumes. Although earlier in 1980s, Boussingault, a French agriculturist, in studies show that legumes are superior to cereals in furnishing the nitrogen to plant. Beijerinck in 1888 isolated bacteria (*Rhizobium*) from root nodules of legumes. Biofertilizer applied differ combination in living microorganisms of bacterial, fungal and algae origin**.** The term "Biofertilizer" or more appropriately a "Microbial inoculants" can generally be defined as preparation containing live or latent cells of efficient strains of Nitrogen fixing, Phosphate solubilising or cellulolytic like microorganisms used for application to seeds, soil or composting areas with the objective of increasing the number of such microorganisms and accelerate those microbial process which augment the availability of nutrients that can be simply assimilated by plants.

It can provide an economically viable support to small and marginal farmers for realizing the ultimate goal of increasing productivity. Biofertilizer is low cost, effective and renewable source of plant nutrients to supplement chemical fertilizers. Micro-organisms are added to the *rhizosphere* of the plant to enhance their activity in the soil. Sustainable production of crop depends on good soil health, soil health maintenance warrants optimum combination of organic and inorganic components often soil. Rapidly use of chemical fertilizers destroys soil biota. Their utility can be enhanced with human intervention by selecting efficient organisms, culturing them and adding them to soils directly or through seeds (Mosa *et al.*, 2018).

Nowadays the agriculture and food industry not only achieve the food needs of a country but also improves the economic condition through agricultural distributes. However, all over the world population is increasing rapidly and is expected to reach 9.0 billion in 2040 year. Due to this population explosion and the changing diets of people there is an expected increase in the demand of food by 70% in 2050. Hunger is previously common in the world with 87 crore people suffering from long-lasting hunger. Option of Biofertilizer is getting very popular as a choice for the replacement of synthetic fertilizer lowering the cost of crop production, enhancing the growth, development and crop yield by supplying and increasing the nitrogen availability and by producing certain substances like auxin, cytokinin and gibberellins, which are helpful in the growth of plants Microbial activity have vital role in agriculture because they are very important in the movement and availability of minerals essential for plant growth and ultimately lower the requirement of synthetic fertilizers (Hegazi and Amer 2007).

The spinach commonly called as palak belonging to family *Chenopodiceae* is one of the most popular vegetable crops grown in India and other parts of the world as leafy vegetable. It is low in calories and with a high biological value, extremely rich in antioxidants especially when fresh steam or quickly boiled. Spinach is a rich source of vitamin A, iron and calcium and also contains appreciable quantity of ascorbic acid, riboflavin and small quantity of thiamine. The leaves are lustrous, bright green in colour, fleshy and accepted by the varied groups of populations. The crop can be harvested 6 to 7 times, with application of nitrogen after each harvest. (Thompson and Kelly, 1957). Effects of biofertilizer and inorganic fertilizers on growth and yield of *Spinacia oleracea.* To compare the phenotypic characteristic of spinach plant in normal v/s Biofertilizer germination/ chemical fertilizer production.

The collective concern for safety of environmental and worldwide demand for pesticide residue free food crop has induced extreme interest in crop production using environment friendly products which are easily biodegradable and do not leave any harmful noxious residues besides conserving nature. So, it is necessary to use natural products like bio-organic formulation to produce chemical residue free food crops and hence bioorganic formulation can play a major role in organic farming. The use of domestic bio-pesticides in the farming practices is old aged practices. It is highly eco- friendly and can obtain from nature directly. It is almost free of cost and there is no adverse impact on human health, soil, animals, plants and environment. Bio-

pesticides are consequential from natural materials such as animals, plants, bacteria, and minerals. Bio-pesticides tend to be less lethal, more quickly biodegradable, and more targeted to the specific pest (US Environmental Protection Agency., 2008). There are number of challenges faced by the agricultural sector at policy, commercial and infrastructural level. Some of the major problems and constraints for organic farming in India includes lack of awareness, output marketing problems, shortage of bio-mass, inadequate supporting infrastructure, high input costs, marketing problems of organic inputs, low yields etc. In order to address the aforesaid challenges in a better way, Jaivik Krishi (JK) package can be developed by using the combination of bio-formulations, which may help common Indian farmers in different parts of the country to produce sustainable organic agricultural crop. In organic agriculture methods is rising, specially in areas where the current harvesting system has degraded resources essential to agricultural production.

Farmers awareness of the conservational costs of agriculture (such as the deteriorating quality of drinking water and soil, and the impact of agriculture on landscape and wildlife) is increasing. The consciousness of eco-friendly health and superiority is often promoted by environmental groups, especially in developed countries. The subsequent demand for organic products creates the opportunity to sell organic products at best prices, enabling organic farmers to continue, and often develop. Products from Cow (Bos indicus) particularly those with hump (Indigenous breed) is one of the key components in agriculture from ancient period. Suggestive evidence indicates that bio-organic food intake may reduce the risk of allergic disease and of overweight and obesity, but residual confounding is likely, as consumers of bio-organic food tend to have healthier lifestyles. It is easily digestible and widely used in Ayurvedic medicines for treatment of various disorders. Milk from indigenous breed of cow is known to have best therapeutic values (R.K. Pathak and R. A. Ram, 2018).

An important produce from Cow is ghee which acts as carrier agent for subtle energies. Another product, cow dung cake has been found to be rich in actinomycetes and was used as medicine in ancient cultures of India, South Asia, North and South America, Scandinavia and eastern and western parts of Europe (A.D.K. Dittrich and A.J. Helden, 2012). Various BOFs have been produced by mixing cow products as described in earlier studies (K. V. Raghavendra *et al.*, 2014). In general, cow products are mixed together in defined ratio and kept in mud pot for few days. This study is focused on the antimicrobial activities of dung extracts of Indian and

imported cows against plant pathogens and their importance as plant growth promoting bio-organic formulations, using tomato as model crop. The increasing concern for environmental safety and global demand for pesticide residue free food has induced extreme interest in crop production using eco-friendly products which are easily biodegradable and do not leave any noxious residues besides conserving nature. So, it is necessary to use natural products like bio-organic formulation to produce chemical residue free food crops and hence bio- organic formulation can play a major role in organic farming.

2. MATERIAL AND METHOD

The seed of spinach were obtained from Prakash chowk Muzaffarnagar marketplace (India). Spinach (*Spinacia oleracea*) is one of the most important vegetable plants in the world. It originated in north India, and domestication is thought to have occurred in all over country. Spinach has been widely used not only as food, but also as research material. Selection is based on important of formulation: -

2.1. Preparation of fermented seed healer (FSH)

Take a plastic container of 2kg with air tight close lid. Weight 1kg Cow dung, 1kg Cow urine, 20gm calcium hydroxide [Ca $(OH)_2$] and 4 litre water, put in the container. Mix all the material in container with a rod. Closed the lid and mixed the material daily with a rod. Let it fermented for 24 hours after 24 hours your seed healer was ready to use for seed treatment.

Table 1: Material for seed healer preparation and seed treatment

S.No.	Material	g/ml	Material	Quantity
1	Plastic container	2000g	Seed healer	1000ml
2	Cow dung	1000g	Seeds	45
3	Calcium hydroxide	20g	Paper	1
4	Water	4000ml	Cotton cloth	Meter
5	Cow urine	1000ml	-	-

i) Treatment of seed with seed healer: Now take a seed healer, seeds, paper and cotton cloth. Take a seed in cotton cloth and soak in seed healer. Now then seeds are dry on the paper. Now seeds are ready to sowing. Now take 6 Petri plates, 1 Blotting paper and washing bottle. Wash the Petri plates by taking water from the washing. Cut the Blotting paper and put it into Petri plate. Sowing the seed five-five control seeds of turnip in 3 Petri plates and into another 3 Petri plates sow the seed from the five- five treatment seed of turnip the germination.

ii) Measurement of germinated seeds: Sprinkle some water daily in Petri plates. Germination can be seen in Petri plates after one day from the sowing. After seven days seeds are fully germinated. After the germination was completed it is seen that the seeds with treatment seeds are better than the control seeds.

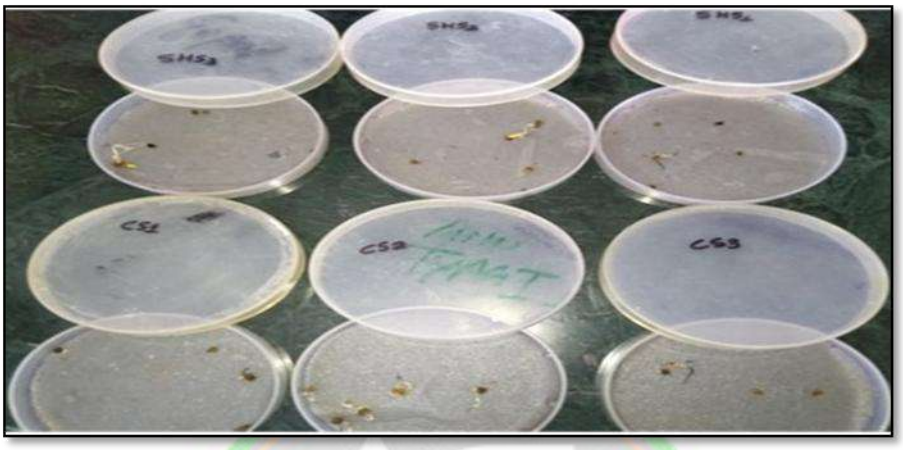


Fig 1: Germination of seeds in petri plates

Table 2: Germination of seed counts in research laboratory conditions

S. No.	Name of petri plates	Total no. of seed in petri plate	Germinated seeds	Not germinated seeds
CONTROL				
1.	CS1	05	04	01
2.	CS2	05	05	00
3.	CS3	05	04	01
SEED HEALER (TREATED SEED)				
1.	SHS1	05	04	01
2.	SHS2	05	02	03
3.	SHS3	05	04	01

Total percentage of germinated control spinach = 86.7

Average of Total percentage of germinated seed healer turnip = 66.3

2.2. Preparation of Liquid Organic Biofertilizer (Jeevamrut)

Take a plastic container of 2.5kg with air tight close lid. Weight 10g jaggery, 2liter water, 10g cow dung, 250 ml cow urine and gram flour 10g in container. Mix all material gently with the help of glass rod and seal it tight and then take a side for a week. After a week check the

container and look bubbles comes out or not then mix gently with the help of a stick. Let it ferment for 30-40 days after nice sweet smell your biofertilizer is ready to use.

Table 3: Materials used preparation of biofertilizer

S. No.	Material	ml/g
1	Cow dung	10g
2	Cow urine	250ml
3	Jaggery	10g
4	Water	2000ml
5	Gramflour	10g
6	Mud under the banyan tree	10g

i) Preparation of pot soil and filling into the pots: Take a 1/2 kg cocopite, 6kg soil and sand, 1kg cow dung by compost. Mix all material with the hand and pour in the pots.

ii) Sowing of vegetable seeds in uniformly prepared pots: Sowing the seed 2-2 control seeds of Spinach in 3 pots and into another 6 pots sow the seed from the 2-2 treatment seeds of Spinach for the germination. Pour water in all pots. now then pour water after 7 days in control spinach pots and into treatment spinach pots pour biofertilizer and into chemical Spinach pots pour liquid urea (DAP). Label the pots with different name and scientific name of Spinach. Now then Mulching in treatment Spinach pots.

iii) Analysis of germinated seeds: Green leaves of germinated seeds. After 1 month of sowing the seed are germinated and 4-5 small leaves are there. After 1 month of sowing the seed are germinated and 10-12 cm in length is there. Height and number of leaves increased and also the size of leaves increased. Seeds are grown in each pot but germinated 1-1 seed in each pot.

iv) Application of organic formulation with irrigation: Organic farms tend to be smaller on average and so their irrigation system should match their scope. It's hard to beat the simplicity of manual irrigation for a tiny organic farm- you can add water when it's needed and let the rain take care of the rest. But once your farm gets a bit bigger, you'll almost certainly need to consider alternatives to manual labour.

2.3. Analysis of phenotypic characters

Plant growth was measured after 60 days taking into account phenotypic characters such as plant height (PH), plant weight (PW), number of leaves (NL), number of plants (NP) and root length

(RL). These phenotypic characters were observed and recorded from 15th-60th day. After 60 days final measurement pf phenotypic characters were documented.

3. RESULT AND DISCUSSION

Firstly, dosage concentration of individual biofertilizer was optimized using research trial. Strikingly, different dosage of DPA, control and biofertilizer affected the growth attributes of trial crop used Spinach. Effect of optimal dosage concentration of each biofertilizer is tabulated in Table 3 and 4. When compared with control, statistically significant increase in NL, PW, PH, NP and RL was observed in case of plants treated with DPA, control and biofertilizer. The percent increase in total biomass of both fresh and dry plants was higher in biofertilizer treated case was found to be higher concentrations of biofertilizer, than control case. Doses of respectively different treatment-based bio fertilizer labelled as (water 1, 2 and 3), (Biofertilizer 1, 2 and 3), and (DAP 1, 2 and 3) shows the effect of different doses of different waste on the growth of Spinach plant.



Fig 2: Growth of Spinach plant after 15, 30 and 40 days from sowing

Different doses show different results with Spinach plants the effect was studied in the following forms (Fig 2). The number of leaves increased and also the size of leaves increased. The plant that grown in biofertilizer has better growth in comparison to plant grown in control and urea. Bio-organic formulation biofertilizer has increasing level of growth than other treatments DPA and control.



Fig 3: Growth of Spinach plant after 60 days from sowing

The plant growth with different treatment tabulation of plant growth parameters on treatment with Biofertilizer and DAP

Table 4: Mean tabulation of First and second observation after sowing 15 and 30 days

Sets	First observation			Second observation		
	NL	PH	NP	NL	PH	NP
Control	6	10.01	2.67	7	13.13	2.67
Biofertilizer	9	12.53	4	11.67	15.73	4
DAP	6	8.9	2	7.67	10.79	2

Table 5: Mean tabulation of third and fourth observation after sowing 45 and 60 days

Sets	Third observation			Fourth observation				
	NL	PH	NP	NL	PH	NP	RL	PW
Control	10	17.49	2.67	14.00	19.79	2.67	14.53	49.63
Biofertilizer	17.33	20.47	20.47	21.33	22.80	04.00	16.18	102.55
DAP	12.67	14.41	14.41	17.00	18.29	02.00	13.56	11.68

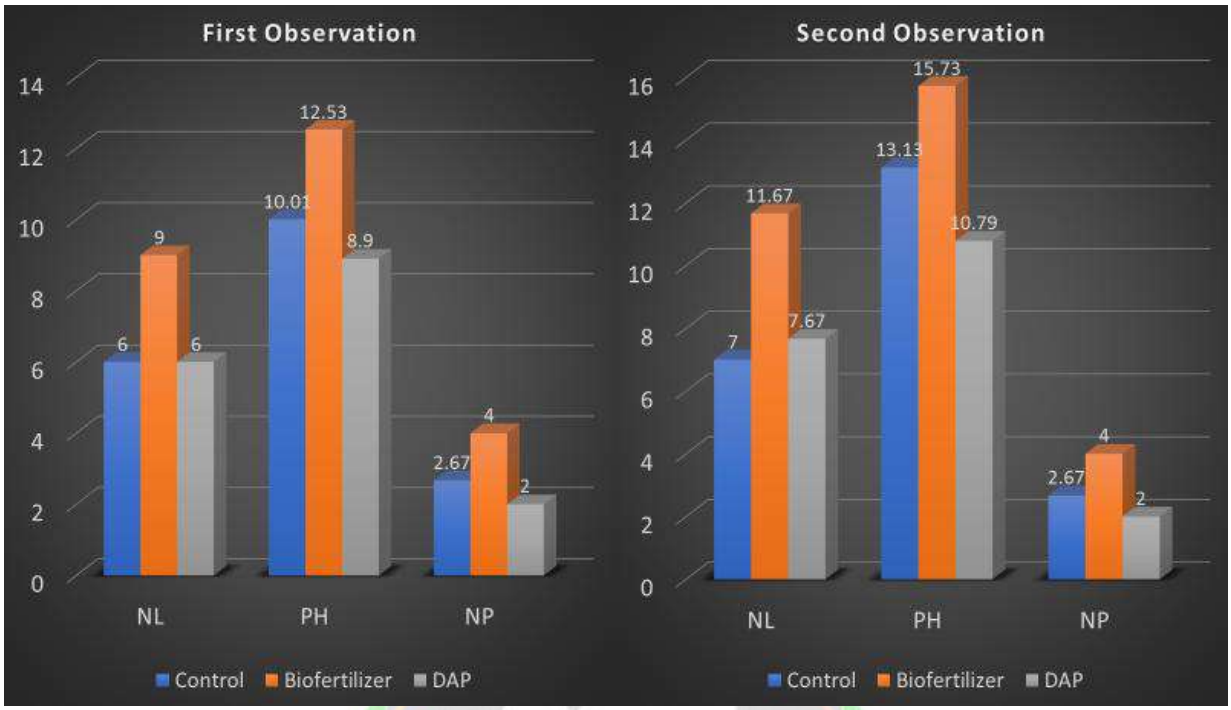


Fig 4: Bar graph represent mean of first and second observations

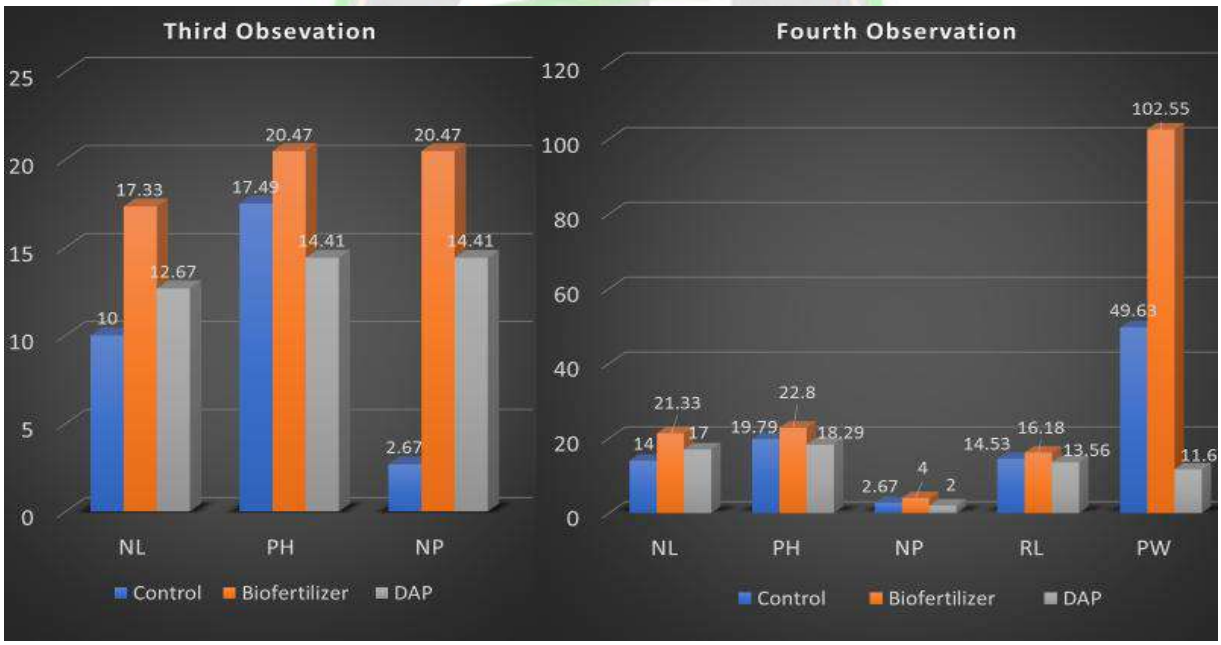


Fig 5: Bar graph represent mean of third and fourth observations

Mean number of leaves is better in high concentration of biofertilizer (21.33) other treatments urea and control. Root length is better in biofertilizer (16.18cm) other treatments such as urea and control. Plant height is better in biofertilizer (22.80cm) other treatments urea and control. Plant weight is better in biofertilizer (102.55g) other treatments urea and control.

A field test was directed during a half year 2019 to contemplate the impact of bio-composts related to inorganic manures on the development and yield of a pea at Shri Ram College Muzaffarnagar, U.P. The test was spread out in a split-plot plan with three replications in sandy topsoil soil. The analysis involved 9 treatment mixes of four degrees of ripeness (Control, PGBM, and Urea). Results demonstrated that the near impact of Panchgavya bio-fertilizer (PGBM) on the development and yield of pea (*Pisum sativum*) was indicated that the plant advancement concerning biomass segments, for example, the mean number of leaf size, leaf length, arial part, root length, root hair, root width, no. of a leaf, full plant size and new weight of plant were expressively impacted by utilized PGBM. A comparable pattern was seen as for leaf length, Fresh weight, and plant stature which were discovered to be essentially higher 45 cm, 136.26 gm/plant, and 60 cm/plant separately. Bio-natural detailing PBGM has an expanding level of development than different medicines. Thus, it very well may be reasoned that PBGM can be the best substitute for compound compost, which has demonstrated constructive outcomes on different harvests with natural manageability (Shiri, T., *et al.*, 2020).

Harvest development is the most significant part of the Indian economy. It provides for development, occupation, and by and large economy of India. The need for expanded food creation in most creating nations like India turns into an extreme objective, to meet the sensational development of their populace. Biomanure builds the dirt ripeness normally and doesn't influence the dirt like substance manures. In this examination, the general impact of Liquid Amla Curd Organic Biomanure (LACOB) on the development and yield of Turnip (Brassica rapa subsp. rapa)" was examined. The seeds of Turnip were treated with LACOB and their outcome was recorded after stretches. It was observed that plants treated with Liquid Amla Curd Organic Biomanure (LACOB) indicated remarkable outcomes in the morphological boundaries when contrasted with controlled plants. The outcomes further indicated that the plant authorization regarding biomass parts, for example, the mean number of leaves, natural product weight, new shoot and root weight, dry shoot and root weight, shoot length, and plant tallness were expressively affected by utilized Biomanure. The absolute plant biomass was discovered to be higher with the utilization of LACOB, DAP, and control when contrasted with a blend of them. The comparative pattern was seen as for organic product weight Fresh shoot weight, Dry shoot weight, and plant stature which was found to be significantly higher 10.34gm/organic product, 8.70gm/plant, 3.94gm/plant, and 60cm/plant individually. Bio-natural definition

LACOB has an expanding level of development than different medicines. Thus, it tends to be inferred that LACOB can be the best substitute for compound compost, which has demonstrated constructive outcomes on different harvests with natural supportability (Shiri, T., *et al.*, 2020).

Conclusion

In this study, it can be concluded that biofertilizer could be a potent source to progress soil fertility, crop productivity and quality. This can also be a probable substitute for fertigation which is becoming common in most of the agriculture crops. However, care should be taken that bio enhancers which are used in limited quantities cannot meet the entire nutrient requirement of the crops. These simply catalyze quick decomposition of organic wastes in to humus, hence incorporation of enough bio mass preferably combination of plant and animal product, which is prerequisite for improving soil fertility and crop productivity. Combined with manures and frequent use of bio enhancers can address many challenges of agriculture and will be surface way for sustainable agriculture through organic resources. It acts as manure for soil and plants. biofertilizer was best pest control as observed in comparison to other treatments. biofertilizer has increasing level of growth than other treatments DAP and control. Mean number of leaves is better in high concentration of biofertilizer (21.33) other treatments. Mean of plant height is better in high concentration of biofertilizer (22.80 cm) other treatments DAP and control. Root length fresh weight of plant respectively 16.18 cm and 102.55 gm are well comparison to other treatments like chemical and control.

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BIOFORTIFICATION: CONCEPT, TYPES, EXAMPLES, PROS AND CONS

Article ID: AG-VO5-I07-08

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Introduction

Biofortification is the process of enhancing the nutritional quality of food crops through agricultural practices or genetic modification. The goal is to increase the nutrient content of staple crops, such as rice, maize, wheat and beans, to improve public health, especially in populations that rely heavily on these crops as their primary food source.

Key Nutrients Targeted by Biofortification:

- **Vitamins**: Vitamin A, Vitamin D and folate.
- **Minerals**: Iron, zinc and selenium.
- **Amino Acids**: Lysine, methionine, etc.
- **Omega-3 Fatty Acids**: Found in certain biofortified crops like algae or canola.

Benefits of Biofortification:

- **Improved Health**: Helps to combat malnutrition and deficiency diseases like vitamin A deficiency, iron-deficiency anemia and zinc deficiency.
- **Cost-Effective**: Unlike supplements or fortified food products, biofortified crops can be grown and consumed locally, often requiring no additional infrastructure or costs.
- **Sustainable**: It can be integrated into the existing farming systems, benefiting farmers in both developing and developed regions.
- **Accessibility**: Biofortified crops are often targeted for regions where nutrient deficiencies are widespread but access to supplementation or fortified foods is limited.

Examples of Biofortified Crops:

- **Golden Rice**: Fortified with vitamin A to combat deficiency.
- **Iron-Rich Beans**: Developed to reduce iron deficiency anemia.
- **Zinc-Enriched Wheat**: Helps address zinc deficiency, which affects immune function.

Challenges:

- **Acceptance**: Some consumer's preferences may be wary of genetically modified organisms (GMOs), which can hinder adoption.
- **Nutrient Bioavailability**: Even if crops contain high levels of a nutrient, it may not always be available for absorption by the human body due to factors like plant composition or food preparation methods.
- **Environmental Factors**: Crops might need specific growing conditions to ensure adequate nutrient accumulation.

Types of Biofortification:

Biofortification can be achieved through various methodologies, depending on the nutrient being targeted and the crops being improved. These methods can be broadly categorized into conventional breeding techniques, genetic engineering and agronomic practices. Here's an overview of the key methodologies used:

1. Conventional Breeding

This approach involves selecting parent plants with desirable traits and crossbreeding them over multiple generations to enhance the nutrient content of crops.

- **Selection of high-nutrient parent plants**: Plants with naturally high levels of the targeted nutrient (e.g., iron, zinc or vitamins) are selected as breeding parents. These plants are then crossed and their offspring are evaluated for higher nutrient content.
- **Mutation breeding**: This involves inducing genetic mutations using radiation or chemicals to create variations in the genetic makeup of plants. Some of these mutations may result in increased nutritional levels. Mutagenesis is a process that has been used to improve the biofortification of crops like maize and wheat.
- **Marker-assisted selection (MAS)**: This technique uses molecular markers to identify desirable traits (such as high nutrient content) in a plant's genetic makeup, speeding up the breeding process. MAS can be particularly helpful when working with traits that are difficult to evaluate visually.

2. Genetic Engineering (GMOs)

Genetic modification involves inserting or altering genes in plants to enhance their nutritional content. This method allows for more precise targeting of specific nutrients that might be challenging to increase using conventional breeding.

- **Gene transfer**: Desired genes, such as those responsible for vitamin or mineral synthesis, are inserted into the plant's genome. For example, *Golden Rice* was developed by inserting genes responsible for the biosynthesis of beta-carotene (pro-vitamin A).
- **CRISPR/Cas9 and gene editing**: CRISPR technology allows for precise edits to the plant genome, enabling researchers to enhance specific traits without introducing foreign genes. This can be a faster and more targeted way to improve the nutrient content of crops compared to traditional genetic engineering.
- **Biotechnology for enhanced nutrient uptake**: Genetic modification can also be used to improve a plant's ability to uptake and accumulate nutrients from the soil, increasing the concentration of those nutrients in the edible parts of the crop.

3. Agronomic Practices

In some cases, the nutritional content of crops can be enhanced through the way they are grown or managed, rather than altering the plant's genetic makeup.

- **Soil management**: By enriching the soil with specific nutrients, plants can take up higher levels of these nutrients. For example, soil enrichment with zinc can result in higher zinc levels in crops like rice and wheat.
- **Fertilization techniques**: Adding micronutrient-rich fertilizers to the soil, especially in regions with nutrient-deficient soils, can boost the nutrient content in crops. Fertilizers rich in iron, zinc or other micronutrients are often used to biofortify staple crops.
- **Foliar spraying**: Nutrient-rich solutions can be sprayed directly onto the leaves of crops, facilitating the absorption of nutrients. This method is especially effective for increasing nutrient concentrations in grains, fruits or vegetables.
- **Crop rotation and intercropping**: Growing nutrient-fortified crops alongside other plants that help increase soil fertility can boost the nutrient levels of the target crop. For example, legumes are often intercropped with other crops to improve soil nitrogen levels.

4. Post-Harvest Processing

In some cases, biofortification can be enhanced after harvest, particularly for crops like legumes, tubers and grains. This includes processing methods that preserve or enhance the nutrient content of crops.

- **Biofortified food products**: After harvesting biofortified crops, further processing techniques, such as milling, fermentation or cooking, can be used to enhance or maintain the nutrient profile. For example, fermentation may increase the bioavailability of certain minerals and vitamins.
- **Storage techniques**: Proper storage conditions (e.g., reducing nutrient loss through optimal storage temperatures and humidity) can help maintain high nutrient levels in biofortified crops until they are consumed.

5. Symbiotic Relationships and Microbial Inoculation

Some biofortification strategies focus on enhancing the crop's relationship with beneficial microbes in the soil, which can help improve nutrient uptake.

- **Microbial inoculants**: Certain bacteria and fungi, such as *Rhizobium* or mycorrhizal fungi, form symbiotic relationships with plants and can enhance nutrient uptake, particularly for minerals like phosphorus, nitrogen and iron.
- **Endophytes**: Beneficial microorganisms that live within the plant tissues can be used to boost the nutrient content of crops. These microorganisms may help the plant to tolerate the environmental stress, improving overall nutrient uptake.

6. Polyploidy and Hybridization

Polyploidy involves increasing the number of sets of chromosomes in a plant, which can sometimes result in larger plants or enhanced nutrient accumulation. Hybridization between different species or varieties can also lead to plants that exhibit superior nutrient profiles.

• **Chromosome doubling**: Inducing polyploidy can sometimes increase the ability of plants to accumulate more of a specific nutrient, as seen in some crops like *tetraploid* wheat, which has increased nutrient density compared to its diploid counterpart.

The methods used for biofortification largely depend on the crop species, the targeted nutrient and the available resources. Conventional breeding and genetic engineering provide the most targeted and long-term solutions, while agronomic practices and post-harvest processing offer more immediate but complementary approaches. These methods can also be combined to

maximize the effectiveness of biofortification efforts, ensuring better nutritional outcomes for populations at risk of malnutrition.

CLASSIC EXAMPLES OF BIOFORTIFICATION

Several examples of biofortified crops have been developed using various biofortification methodologies to improve nutritional content, especially in regions where nutrient deficiencies are widespread. Here are some of the most well-known and impactful examples:

1. Golden Rice (Vitamin A)

- **Target Nutrient**: **Vitamin A** (pro-vitamin A or beta-carotene)
- **Method**: **Genetic Engineering**
- **Description**: Golden Rice is one of the well-known examples of biofortification. It was genetically engineered to produce beta-carotene in the rice grains. Beta-carotene is a precursor of vitamin A, which is highly essential for vision, immune function and skin health. Vitamin A deficiency is a major cause of blindness in children in many developing countries.
- **Significance**: Golden Rice has the potential to provide a sustainable solution to vitamin A deficiency, which affects millions of people, particularly in Southeast Asia and sub-Saharan Africa.

2. Iron-Biofortified Crops (Iron)

- **Target Nutrient**: **Iron**
- **Method**: **Conventional Breeding and Genetic Engineering**
- **Description**: Several crops have been biofortified with iron to help combat iron-deficiency anemia, one of the most common micronutrient deficiencies worldwide. Iron-rich varieties in crops like rice, beans and wheat have been developed. One notable example is iron-fortified **beans** and **rice**.
- **Significance**: Iron deficiency affects millions of people, especially women and children. Iron-biofortified crops can help to increase iron intake among people that rely heavily on staple crops like rice and beans.

3. Zinc-Biofortified Crops (Zinc)

- **Target Nutrient**: **Zinc**
- **Method**: **Conventional Breeding**

- **Description**: Zinc deficiency is prevalent in many developing countries, leading to impaired immune function, growth retardation and other health issues. Zinc-enriched varieties of staple crops like **wheat**, **rice** and **maize** have been developed to tackle this deficiency.
- **Significance**: Zinc-biofortified wheat has been widely adopted in countries like India and Pakistan. Zinc is crucial for immune system function, cell division and the synthesis of proteins and its deficiency is linked to stunted growth and increased disease susceptibility.

4. High-Vitamin A Maize (Vitamin A)

- **Target Nutrient**: **Vitamin A**
- **Method**: **Conventional Breeding and Genetic Engineering**
- **Description**: Biofortified **maize** (corn) with increased levels of provitamin A (beta-carotene) has been developed in sub-Saharan Africa to help fight vitamin A deficiency. Maize is a major staple crop in many African countries, where vitamin A deficiency is a significant health concern.
- **Significance**: This variety of maize provides a more accessible source of vitamin A to populations who may not have access to other vitamin A-rich foods like fruits and vegetables.

5. Folic Acid-Biofortified Wheat (Folate)

- **Target Nutrient**: **Folate (Vitamin B9)**
- **Method**: **Genetic Engineering**
- **Description**: Folate (vitamin B9) is crucial for cell growth, particularly during pregnancy period. Biofortified **wheat** varieties with increased folate content have been developed, particularly in regions where folate deficiency is common.
- **Significance**: Folate deficiency can lead to birth defects, including neural tube defects, and is associated with anemia. Biofortified wheat is an affordable and effective way to address folate deficiency.

6. High-Lysine Maize (Lysine)

- **Target Nutrient**: **Lysine** (an essential amino acid)
- **Method**: **Conventional Breeding**

- **Description**: **Maize** traditionally has low levels of lysine, an essential amino acid required for protein synthesis and growth. Through conventional breeding, maize varieties with higher lysine content often referred to as **Quality Protein Maize (QPM)**, have been developed.
- **Significance**: Lysine is an essential amino acid that is often limiting in diets that rely heavily on grains. The biofortification of maize with higher lysine content helps improve protein quality in diets, especially in areas where maize is a staple food.

7. High-Omega-3 Canola (Omega-3 Fatty Acids)

- **Target Nutrient**: **Omega-3 Fatty Acids**
- **Method**: **Genetic Engineering**
- **Description**: **Canola** (rapeseed) has been genetically engineered to produce higher levels of omega-3 fatty acids, particularly **eicosapentaenoic acid (EPA)** and **docosahexaenoic acid (DHA)**. This essential fatty acid plays a vital role in heart and brain health.
- **Significance**: Omega-3 fatty acid deficiency is linked to cardiovascular diseases and poor cognitive function. This biofortification effort aims to provide a more sustainable and widely available source of omega-3s, particularly in regions where fish consumption is low.

8. Iron and Zinc-Biofortified Pearl Millet (Iron and Zinc)

- **Target Nutrients**: **Iron and Zinc**
- **Method**: **Conventional Breeding**
- **Description**: **Pearl millet** is a drought-tolerant crop that is a staple in parts of Africa and India. Through conventional breeding, varieties of pearl millet with enhanced iron and zinc content have been developed to combat the widespread deficiencies of these minerals.
- **Significance**: The development of biofortified pearl millet provides a nutritious, climate-resilient option for addressing micronutrient deficiencies in arid regions where traditional agricultural methods may be less productive.

PROS AND CONS OF BIOFORTIFICATION

Biofortification has become an increasingly important strategy to combat malnutrition, particularly in regions where micronutrient deficiencies are widespread. However, like any

technology or approach, it has both advantages and disadvantages. Here's a breakdown of the **pros and cons of biofortification:**

Pros of Biofortification

1. **Improved Nutritional Quality**:

- **Targeted Nutrient Delivery**: Biofortified crops are specifically designed to address common micronutrient deficiencies, such as iron, zinc and vitamin A, providing essential nutrients directly through the foods people already eat. This can be a particularly effective way to combat deficiencies in populations that rely on a limited diet.
- **Prevention of Deficiency Diseases**: Biofortified crops can help prevent deficiency-related health issues like anemia (due to iron deficiency), blindness (due to vitamin A deficiency) and stunted growth (due to zinc deficiency), improving public health outcomes.

2. **Sustainability and Cost-Effectiveness**:

- **No Need for Ongoing External Inputs**: Unlike supplements or fortified foods, biofortified crops do not require continuous external resources such as supplements, fortified foods or expensive manufacturing processes. They can be grown locally, making them more sustainable and cost-effective in the long run.
- **Accessibility**: Biofortified crops are often staples that people already consume, meaning the nutritional improvements are naturally integrated into the local food systems. This reduces the need for extra infrastructure, like food distribution or education programs.

3. **Improved Food Security**:

- **Resilience Against Nutrient Deficiencies**: In regions where nutrient-rich foods are scarce or too expensive, biofortified crops offer a stable and accessible solution for addressing malnutrition without needing to rely on imported or processed foods.
- **Increased Yields and Climate Resilience**: Many biofortified crops are bred for better disease resistance, drought tolerance and higher yields, which contributes to greater food security in areas that experience environmental stress.

4. **Long-Term Solution**:

    - **Permanence**: Once biofortified crops are developed and adopted, they offer a long-term solution that continues to provide nutritional benefits year after year, unlike short-term interventions like food aid or supplementation programs.

5. **Scalability**:

- **Global Reach**: Biofortified crops can be adopted across regions with different climates and agricultural practices. Once they are developed, they can be grown by a wide range of farmers, from smallholders to large-scale producers, improving nutrient intake in a scalable way.

Cons of Biofortification

1. **Limited Nutrient Improvements**:

- **May Not Address All Deficiencies**: While biofortification can significantly improve the levels of certain nutrients (like iron, zinc and vitamin A), it is not a solution for all forms of malnutrition. It focuses on specific nutrients and may not address broader dietary inadequacies, such as protein, carbohydrates or other vitamins.
- **Bioavailability**: Even if a crop has higher nutrient levels, the bioavailability (how much of the nutrient the body can actually absorb and use) can be influenced by factors like the plant's chemical composition, soil quality and food preparation methods. For example, iron in biofortified crops may not be as easily absorbed in individuals with low levels of vitamin C.

2. **Acceptance and Cultural Barriers**:

- **Resistance to GMOs**: Genetically modified (GM) crops, such as Golden Rice and biofortified maize, often face resistance due to concerns over health, environmental impact or ethical reasons. Public skepticism about GMOs, especially in certain regions, may slow adoption of biofortified crops.
- **Cultural Preferences**: In some regions, there may be resistance to changing traditional food systems or to introducing new crop varieties, even if they are more nutritious. People may be hesitant to adopt biofortified crops because they are unfamiliar or perceived as unnatural.

3. **Environmental and Ecological Risks**:

- **Biodiversity Concerns**: Widespread adoption of biofortified varieties could lead to a reduction in genetic diversity if only a few varieties become dominant. This could make crops more vulnerable to pests, diseases and environmental changes, particularly in areas with changing climate conditions.
- **Cross-Breeding with Non-Biofortified Crops**: There is a risk that biofortified crops could cross-breed with non-biofortified crops, leading to unintended consequences such as changes in nutrient content or loss of local crop varieties.

4. **Economic Considerations**:

- **High Initial Research and Development Costs**: The development of biofortified crops, especially through genetic engineering, can be expensive and time-consuming. This could be a barrier for low-income countries or smaller organizations that may not have the necessary resources to invest in research.
- **Market Penetration**: Even after development, biofortified crops may struggle to gain widespread adoption, especially if there are logistical challenges related to distribution, seed availability or farmer education.

5. **Nutrient Overload**:

- **Excessive Nutrient Intake**: In some cases, excessive biofortification could lead to nutrient imbalances or toxicity. For example, if biofortified crops are consumed in large quantities, there could be an overconsumption of certain nutrients, which may have negative health effects, such as iron overload.

6. **Dependence on Agronomic Factors**:

- **Soil and Climate Variability**: The nutrient content of biofortified crops can be affected by soil fertility and climate conditions. Poor soil conditions, inadequate fertilization or drought stress could limit the nutrient benefits of biofortified crops, making them less reliable in some environments.

Conclusion

Biofortification offers a promising and sustainable solution to the global challenge of micronutrient deficiencies, especially in regions with limited access to diverse diets. It has the potential to significantly improve public health, food security and agricultural resilience. However, its effectiveness depends on various factors, including cultural acceptance, environmental conditions and careful management of nutrient bioavailability. While biofortification is not a one-size-fits-all solution, it represents a important tool in a broader strategy to combat malnutrition and its benefits could be amplified when combined with other interventions like education, supplementation programs and improved agricultural practices.

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TYPES, IMPORTANCES, GENETIC AND EVOLUTIONARY IMPLICATIONS OF VEGETATIVE REPRODUCTION

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Introduction

Vegetative reproduction, also known as vegetative propagation, is a type of asexual reproduction in plants where new individuals develop from vegetative parts of the parent plant, such as stems, roots, or leaves, rather than from seeds or spores. Essentially, a fragment of the parent plant grows into a new, independent plant.

Types of Vegetative reproduction in plants:

1. Natural Vegetative Reproduction

This type of reproduction occurs naturally without any human intervention. Plants have developed various specialized structures that facilitate this process. Some common methods include:

- **By Roots:**
  - **Root Tubers:** Swollen, modified roots that store food and have buds that can develop into new plants (e.g., sweet potato and dahlia).
  - **Adventitious Roots:** Roots that arise from parts of the plant other than the existing root system (e.g., stems or leaves). These roots can develop into new plants (e.g., some grasses and willows).
- **By Stems:** Stems are the most common plant parts involved in natural vegetative reproduction. Various modified stems are used:

- **Rhizomes:** Horizontal underground stems with nodes and internodes. Buds at the nodes can develop into new shoots and roots (e.g., ginger, turmeric, bamboo, ferns and irises).
- **Runners (Stolons):** Horizontal stems that grow above the ground. They have nodes that can develop into new plantlets when they come into contact with the soil (e.g., strawberry and lawn grasses).
- **Tubers:** Swollen underground stems that store food. They have "eyes" which are actually buds that can sprout into new plants (e.g., potato and yam).
- **Bulbs:** Underground stems with fleshy, scale-like leaves that store food. They contain a central bud that develops into a new plant, and lateral buds can also form new bulbs (e.g., onion, garlic, tulips, daffodils and lilies).
- **Corms:** Solid, fleshy underground stems that store food, unlike bulbs which have fleshy leaves. They have buds that can develop into new plants (e.g., gladiolus, crocus and colocasia).
- **Offsets:** Small daughter plants that develop laterally from the base of the stem of the parent plant. These can be separated and grown independently (e.g., water hyacinth and pineapple).
- **Suckers:** New shoots that arise from buds on underground roots or the lower part of the stem. These can grow into new plants (e.g., mint, raspberry and poplar).

- **By Leaves:** In some plants, leaves can develop adventitious buds along their margins or on their surface. These buds can develop into new plantlets that eventually detach and grow into independent plants (e.g., *Bryophyllum* (Kalanchoe) and *Begonia*).
- **Fragmentation:** In some cases, a part of the parent plant naturally breaks off and develops into a new individual under favorable conditions (e.g., some algae, liverworts and willows).

2. Artificial Vegetative Reproduction

These are methods employed by humans for the propagation of plants, often in agriculture and horticulture, to obtain desired traits or to propagate plants that do not readily reproduce naturally or from seeds. Common methods include:

- **Cutting:** A piece of stem, leaf, or root is cut from the parent plant and planted in a suitable medium. Under favorable conditions, it develops roots and grows into a new

plant. Sometimes, cuttings are treated with rooting hormones to encourage root development (e.g., rose, sugarcane, *Coleus* and *Hibiscus*).

- **Layering:** A stem attached to the parent plant is bent and a portion of it is covered with soil. Adventitious roots develop from the covered part. Once roots have formed, the rooted section (layer) is cut from the parent plant and grown as a new individual (e.g., jasmine, strawberry, grapes and *Bougainvillea*). There are different types of layering, including ground layering, air layering (marcotting), and mound layering.
- **Grafting:** A part of a desired plant (scion) is attached to the rooted stem (stock or rootstock) of another plant. The tissues of the scion and stock join together, and the scion grows as a part of the stock. This method combines the desirable characteristics of two plants, such as disease resistance of the rootstock and superior fruit quality of the scion (e.g., mango, apple, citrus fruits and roses). Bud grafting (budding) is a specific type of grafting where a bud is used as the scion.
- **Tissue Culture (Micropropagation):** Plant cells, tissues, or organs are grown in a sterile nutrient medium in a laboratory. This technique allows for the rapid production of a large number of genetically identical plants from a small piece of parent tissue. It is used for the propagation of rare or endangered species, disease-free plants, and for mass production of commercially important plants (e.g., orchids, bananas and strawberries).
- **Suckering:** Encouraging and then separating suckers (shoots arising from the base or roots) to grow into new plants (e.g., banana and bamboo).
- **Division:** Separating a mature plant into smaller parts, each with its own roots and shoots, which can then grow into new independent plants (e.g., ferns, grasses and some ornamental plants).

Vegetative reproduction, both natural and artificial, has numerous important uses across various fields:

1. Agriculture and Horticulture:

- **Rapid and Efficient Propagation:** It allows for the quick multiplication of desirable plant varieties, saving time and resources compared to growing from seeds.
- **Preservation of Desired Traits:** It ensures that offspring are genetically identical to the parent plant, maintaining valuable characteristics like fruit quality, flower color, disease resistance, and yield. This is crucial for maintaining the consistency of commercial crops.

- **Production of Seedless Varieties:** Plants that do not produce viable seeds (e.g., bananas, some grapes and pineapples) can only be propagated vegetatively.
- **Overcoming Seed Dormancy and Viability Issues:** It bypasses problems associated with seed germination, such as dormancy periods or low viability.
- **Faster Time to Maturity:** Vegetatively propagated plants often mature and produce flowers and fruits earlier than seed-grown plants.
- **Combining Desirable Traits (Grafting):** Grafting allows combining the beneficial traits of two different plants, such as a disease-resistant rootstock with a scion that produces high-quality fruit.
- **Large-Scale Production (Tissue Culture):** Micropropagation enables the rapid production of a large number of genetically identical, disease-free plants in a controlled laboratory setting.
- **Recovery After Damage:** In natural environments, if a plant is damaged, vegetative parts like rhizomes or suckers can facilitate regrowth and the establishment of new individuals.

2. Conservation:

- **Propagation of Rare and Endangered Species:** When seed production is low or unreliable, vegetative propagation techniques like cuttings or tissue culture can be used to increase the population size of threatened plant species.
- **Maintaining Genetic Diversity (within a clone):** While it doesn't create new genetic diversity, propagating existing individuals ensures the survival of unique genotypes that might be lost through sexual reproduction.

3. Forestry:

- **Reforestation and Afforestation:** Vegetative propagation can be used to quickly establish forests with genetically superior trees selected for traits like fast growth and disease resistance.
- **Clone Banks:** Forest geneticists use vegetative propagation to create clone banks, preserving the genetic material of selected trees for future breeding programs.

4. Research:

- **Genetic Studies:** Clones produced through vegetative reproduction are valuable tools in genetic research as they provide genetically uniform material for experiments.

- **Physiological Studies:** Studying clones allows researchers to isolate the effects of environmental factors on plant growth and development, as the genetic variable is eliminated.

5. Landscaping and Gardening:

- **Easy Propagation of Favorite Plants:** Gardeners can easily multiply their favorite plants through simple methods like cuttings, layering and division.
- **Creating Specific Garden Designs:** Vegetative propagation allows for the creation of uniform plant groupings and specific landscape designs with predictable characteristics.

Genetic implications of vegetative reproduction:

Vegetative reproduction, as a form of asexual reproduction, has significant genetic implications for plants and their populations. Here's a breakdown of its genetic significance:

1. Production of Genetically Identical Offspring (Clones):

- The most defining genetic characteristic of vegetative reproduction is that it produces offspring that are genetically identical to the parent plant.
- Since it involves mitotic cell division and the development of a new plant from a part of the parent's somatic tissue (stem, root, or leaf), there is no fusion of gametes and therefore no genetic recombination or segregation of genes as seen in sexual reproduction.
- The resulting individuals are essentially clones of the parent, possessing the same genetic makeup. This is why vegetative propagation is also known as clonal propagation.

2. Maintenance of Genetic Uniformity:

- Vegetative reproduction allows for the faithful preservation of the parent plant's genotype across generations.
- If a plant has a particularly desirable set of traits, such as high yield, disease resistance, specific flower color, or unique growth habit, vegetative propagation ensures that these traits are passed on uniformly to its offspring.
- This is particularly valuable in horticulture and agriculture for maintaining the quality and consistency of crops and ornamental plants.

3. Lack of Genetic Variation:

- A significant consequence of producing genetically identical offspring is the absence of genetic variation within a population established through vegetative reproduction

- This lack of diversity can be a major disadvantage from an evolutionary perspective. A genetically uniform population is more vulnerable to environmental changes, new diseases, or pests. If one individual is susceptible, the entire population is likely to be affected.
- In contrast, sexual reproduction generates genetic diversity through recombination and independent assortment, increasing the chances that some individuals will possess traits that allow them to survive and adapt to changing conditions.

4. Accumulation of Mutations:

- While vegetative reproduction generally produces genetically identical offspring, new mutations can still arise in the somatic cells of the parent plant.
- If a new plant develops from a part of the parent that has accumulated a somatic mutation, this mutation will be passed on to the offspring.
- Over long periods of vegetative propagation, there is a risk of accumulating deleterious mutations within a lineage, a phenomenon known as Muller's ratchet, as there is no mechanism like meiosis to eliminate these harmful genetic changes.

5. Impact on Evolution and Adaptation:

- The limited genetic variation in vegetatively reproducing populations can hinder their ability to adapt to new environmental conditions or the emergence of new pathogens.
- While vegetative reproduction allows for rapid colonization of a stable environment where the parent plant is well-suited, it can be a liability in the face of environmental change.
- For long-term survival and evolutionary success, most plant species rely on a combination of both sexual and asexual reproduction to balance the benefits of genetic stability in favorable conditions with the adaptability provided by genetic diversity.

6. Implications for Plant Breeding and Conservation:

- **Plant Breeding:** Vegetative propagation is a crucial tool in plant breeding for maintaining desirable traits selected through sexual hybridization. Once a superior genotype is obtained, it can be multiplied clonally to produce a uniform crop. Techniques like grafting and tissue culture rely on this principle.
- **Conservation:** For rare or endangered plant species that may have low seed viability or germination rates, vegetative propagation can be an important method for increasing

population numbers and preserving the existing genetic diversity (although it doesn't create new diversity).

The genetic significance of vegetative reproduction lies in its ability to produce genetically uniform offspring, ensuring the perpetuation of desirable traits. However, this lack of genetic diversity can make populations more vulnerable to environmental stresses and limit their evolutionary potential. While advantageous in specific ecological and agricultural contexts, the absence of genetic recombination has long-term evolutionary implications for plant species that rely primarily on vegetative reproduction. Vegetative reproduction doesn't directly drive the creation of new genetic variations like sexual reproduction, it plays several indirect but significant roles in the evolutionary processes of plants:

1. Rapid Colonization and Expansion:

- Vegetative reproduction allows plants well-adapted to a specific environment to rapidly multiply and colonize a larger area. This quick expansion can lead to a higher prevalence of successful genotypes in stable environments.
- For example, a plant with traits that make it particularly efficient at nutrient uptake or light capture in a specific habitat can quickly spread through rhizomes or runners, outcompeting less adapted individuals in the immediate vicinity.

2. Persistence in Stable Environments:

- In environments that remain relatively constant over long periods, the ability to produce genetically identical offspring can be advantageous. It ensures the continuation of well-suited genotypes without the risks associated with genetic recombination in sexual reproduction (where beneficial combinations might be lost).
- Perennial plants that rely heavily on vegetative reproduction can persist in a location for extended periods, forming clonal colonies.

3. Exploiting Favorable Mutations:

- Although vegetative reproduction doesn't generate new genetic combinations, it can effectively propagate individuals that have acquired beneficial somatic mutations. If a mutation arises in a vegetative part that enhances survival or reproduction, the new plants arising from that part will also carry the mutation. Over a period of time, this can lead to the spread of advantageous traits within a localized population.

4. Escape from Sexual Reproduction Limitations:

- Vegetative reproduction can be crucial for plants that face limitations in sexual reproduction, such as:
    - **Seed sterility:** Hybrid plants or polyploids may have reduced fertility or produce non-viable seeds. Vegetative propagation allows them to reproduce effectively despite this.
    - **Unreliable pollination:** In environments where pollinators are scarce or unreliable, vegetative reproduction offers a guaranteed method of propagation.
    - **Long juvenile periods:** Plants that take a long time to reach sexual maturity can reproduce vegetatively, allowing them to spread and establish themselves more quickly.

5. Facilitating Adaptation to Local Conditions:

- While lacking broad genetic diversity, clonal populations can exhibit micro-evolutionary adaptations to very specific local conditions through somatic mutations and epigenetic changes. If a particular clone thrives in a certain microhabitat, vegetative spread can maximize its success in that niche.

However, it's crucial to acknowledge the limitations of vegetative reproduction in the context of evolution:

- **Lack of Genetic Diversity:** The primary drawback is the absence of significant genetic variation. This makes vegetatively reproducing populations lesser adaptation to new environmental challenges, diseases, or pests. A single threat can potentially wipe out entire clonal populations.
- **Slower Evolutionary Rate:** Without the constant shuffling of genes through sexual reproduction, the rate of evolution in purely vegetative lineages is generally slower, relying solely on the relatively infrequent occurrence and spread of beneficial mutations.
- **Accumulation of Deleterious Mutations (Muller's Ratchet):** In the absence of recombination, harmful mutations can accumulate over generations in asexual lineages, potentially leading to a decline in fitness over time.

Vegetative reproduction doesn't drive the initial creation of genetic diversity, it plays a significant role in the ecological success and persistence of certain plant genotypes, especially in stable environments or when sexual reproduction is limited. It allows for rapid spread of

successful individuals and the exploitation of beneficial somatic mutations. However, the inherent lack of genetic diversity makes populations relying solely on vegetative reproduction potentially vulnerable to environmental changes and may limit their long-term evolutionary potential. Many plant species utilize a combination of both asexual and sexual reproduction to balance the advantages of adaptability and genetic stability.

Conclusion

The natural and artificial methods of vegetative reproduction play a crucial role in the survival, propagation and cultivation of a wide variety of plant species. It is a powerful strategy for plant propagation, offering benefits in terms of speed, genetic consistency, and adaptation, making it ecologically significant and agriculturally valuable. It is a vital tool in various fields due to its efficiency in producing genetically identical offspring, its ability to bypass limitations of sexual reproduction, and its role in conservation efforts. From ensuring consistent crop yields to preserving endangered species, its applications are widespread and significant.

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HEALING THE EARTH THROUGH REGENERATIVE AGRICULTURE

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Abstract

The world today is facing big problems like climate change, poor soil health and not enough food for everyone. Traditional farming methods have made these issues worse by using too many chemicals and damaging the land. But a new approach called regenerative agriculture is offering hope. Regenerative agriculture is a way of farming that focuses on healing the soil, improving the environment and growing healthy food. It uses natural methods like growing different crops, using compost, keeping the soil covered and including animals in the farming system. These practices help store carbon in the soil, save water, increase biodiversity and make farms more resilient to climate change. This method not only helps the planet but also supports farmers and communities. Regenerative agriculture is a positive step towards a healthier more sustainable future.

Introduction

Across the globe, people are becoming increasingly aware of the serious challenges facing our environment and food systems. Climate change is causing unpredictable weather, droughts and floods. At the same time, years of using chemical-based farming methods have led to poor soil health and declining crop quality (Bohme *et al*., 2005). As a result, many communities are struggling with food insecurity and farmers are finding it harder to sustain their land and livelihoods. In response to these growing problems a promising solution is gaining attention- regenerative agriculture. Unlike traditional farming, which often focuses on short-term yields, regenerative agriculture takes a long-term view. It aims to repair the damage done to the land while producing healthy food in harmony with nature. By using techniques such as crop

rotation, composting, cover cropping and integrating animals, regenerative farming helps restore soil fertility, reduce pollution, improve biodiversity and even capture carbon from the atmosphere. This approach is not just about growing food, it's about regenerating ecosystems, empowering farmers and building a more resilient and sustainable future for everyone. In this article, we explore what regenerative agriculture is, how it works and why it could be the key to solving some of the world's most urgent environmental and agricultural challenges.

What Is Regenerative Agriculture?

Unlike conventional farming that often depletes soil and relies heavily on chemical inputs, regenerative agriculture focuses on restoring and enhancing natural ecosystems. It works with nature, not against it. The core idea is simple. Healthy soil leads to healthy crops, healthier animals and a healthier planet.

Why Does It Matter?

- **Soil Health Crisis:** Over 30% of the world's soil is degraded. Regenerative practices rebuild soil structure and fertility.
- **Climate :** Soils can store massive amounts of carbon. Healthy soils are a powerful weapon against global warming.
- **Food Security:** Healthier soil grows more nutritious and resilient crops.
- **Water Conservation:** Regenerative farms retain more rainwater, reducing irrigation needs and protecting against droughts.

Key Principles of Regenerative Farming

1. **Cover Cropping:** is the practice of growing specific crops like legumes and grasses during the off-season to protect and improve soil health. These crops are not grown for harvest but help prevent soil erosion, suppress weeds, enhance soil fertility and increase organic matter. By covering the soil, they reduce nutrient loss, improve moisture retention and support beneficial soil microbes making the land more productive and sustainable for future crops.
2. **Minimal Tillage:** It involves reducing how much the soil is disturbed during farming. This helps keep carbon stored underground, improves soil structure and protects beneficial microbes and earthworms. It reduces erosion, conserves moisture and supports long-term soil health.

3. **Crop Diversity:** Growing a variety of crops through rotation or intercropping improves soil fertility, breaks pest and disease cycles and reduces dependence on chemical inputs. Diverse crops enhance nutrient balance in the soil and make farming systems more resilient to climate.
4. **Integrating Livestock:** Including cattles, goatery and poultry on farms helps recycle nutrients through manure, which naturally fertilizes the soil. Livestock also help manage weeds and crop residues creating a more balanced and sustainable farming ecosystem.
5. **Composting and Organic Inputs:** This practice focuses on feeding the soil rather than just the crop. Using compost, manure and plant residues adds organic matter, improves soil structure and enhances microbial life. It reduces the need for synthetic fertilizers and promotes healthier more fertile soil.

Regenerative agriculture is about **regenerating communities, economies and ecosystems**. It supports small farmers, protects biodiversity and connects consumers with how their food is grown.

Regenerative Agriculture vs. Organic Farming vs. Natural Farming

These three approaches all focus on sustainable and eco-friendly farming but they differ in goals, methods and philosophy. Here's a clear comparison:

Aspect	Regenerative Agriculture	Organic Farming	Natural Farming
Main Goal	Restore & improve ecosystems	Avoid chemicals sustain health	Mimic natural ecosystems
Use of Fertilizers	Organic and composted inputs	Allowed if organic	Avoided
Soil Disturbance	Minimal tillage encouraged	Varies often tilled	No tilling
Certification	Not always certified	Requires formal certification	No certification needed
Core Principle	Regeneration	Substitution of inputs	Harmony with nature

Conclusion

In a world facing the dual crises of environmental degradation and food insecurity, the path forward lies not just in growing more but in growing better. Regenerative agriculture offers a hopeful vision the farming heals the earth, enriches the soil and nurtures life above and below ground. While organic and natural farming have laid strong foundations by eliminating harmful practices and reconnecting us with nature, regenerative agriculture goes a step further, actively restoring what has been lost. It invites us to become stewards of the land, working in harmony with nature's rhythms to create farms that are not only productive, but resilient, vibrant and alive. By embracing such holistic practices, we plant not just seeds for the next harvest but roots for a thriving and sustainable future.

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FARMER PRODUCER ORGANIZATIONS: STRENGTHENING AGRICULTURAL EXTENSION THROUGH COLLECTIVE EMPOWERMENT

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Introduction

Agricultural extension in India has historically relied on the Transfer of Technology (ToT) model, focusing on linear dissemination of innovations. However, with the growing complexity of agriculture, fragmentation of landholdings, and the need for localized solutions, traditional methods have proven inadequate. In response, participatory and group-based extension approaches have gained prominence. Among these, Farmer Producer Organizations (FPOs) have emerged as a promising institutional innovation. By aggregating farmers, FPOs aim to enhance bargaining power, reduce transaction costs, and serve as platforms for information exchange and technology dissemination. This paper explores how FPOs can be integrated into extension systems to deliver timely, relevant, and location-specific advisories and services.

Conceptual Framework of FPO

FPOs are collective entities formed by farmers under legal structures such as the Companies Act or Co-operative Societies Act. Supported by institutions like SFAC, NABARD, and the Ministry of Agriculture, FPOs are designed to address the challenges of scale in smallholder agriculture. They facilitate input procurement, collective marketing, credit access, and capacity building. The government's initiative to promote 10,000 FPOs across the country underscores their strategic importance in rural development. As group-based institutions, FPOs are uniquely positioned to complement and enhance public extension systems by acting as intermediaries between farmers and technology providers.

FPOs as an Emerging Extension Strategy FPOs play a multifaceted role in agricultural extension:

- **Training and Capacity Building:** FPOs collaborate with Krishi Vigyan Kendras (KVKs), NGOs, and line departments to organize skill-based training and exposure visits.
- **Technology Dissemination:** Through demonstrations, farmer-to-farmer learning, and ICT tools, FPOs facilitate the adoption of improved practices and inputs.
- **Information and Advisory Services:** Some FPOs provide real-time market information, weather updates, and crop advisories, enhancing decision-making.
- **Demand Articulation:** FPOs can articulate member needs, ensuring that extension services are demand-driven and relevant to local contexts.
- Farmer Producer Organizations (FPOs) differ significantly from conventional agricultural extension strategies in structure, function, and delivery mechanisms. Traditional extension models, particularly the Transfer of Technology (ToT) approach, have been largely top-down and individual-centric, focusing on disseminating generic technologies to farmers (Röling & de Jong, 1998). In contrast, FPOs follow a collective, demand-driven model that emphasizes participatory decision-making, market integration, and peer learning (Singh & Meena, 2021). As farmer-led institutions, FPOs function not only as recipients but also as providers of extension, thereby enhancing ownership and sustainability (NABARD, 2022). They facilitate localized, need-based advisories by aggregating farmer needs and acting as intermediaries between knowledge institutions and the farming community (Ministry of Agriculture & Farmers Welfare, 2020). This positions FPOs as more holistic and inclusive platforms for rural transformation.

Aspect	**Traditional Extension Strategies**	**FPO-based Extension**
Approach Type	Mainly *individual-centric* (e.g., one-to-one advisory)	*Group-based, collective approach*
Information Flow	Top-down (Transfer of Technology model)	Bottom-up (demand-driven and participatory)
Focus	Technology dissemination, awareness creation	Technology + marketing + aggregation + empowerment

Aspect	Traditional Extension Strategies	FPO-based Extension
Actors Involved	Government officers (like AOs, KVK staff), scientists	Farmer leaders, CEOs, FPO members, supported by extension agencies
Mode of Delivery	Farm visits, training camps, mass media	Peer learning, cluster meetings, ICT tools via FPO networks
Sustainability	Often project-dependent	Higher sustainability due to farmer ownership
Customization	Generic recommendations	Localized and crop-specific, based on member needs
Reach	Often limited by manpower	Wider reach through aggregation of farmers
Market Linkages	Weak integration with market systems	Strong integration—FPOs double as marketing institutions
Empowerment	Passive recipient model	Active farmer participation, leadership development

Challenges in Using FPOs for Extension Delivery

1. **Limited Capacity and Skills**
   - Many FPOs lack trained staff and leadership to manage extension activities effectively.
   - Weak technical knowledge in agriculture, marketing, and modern practices.
2. **Financial Constraints**
   - Inadequate funding for organizing regular training, field demonstrations, or hiring experts.
   - Dependency on external grants and subsidies limits sustainability.
3. **Low Member Participation**
   - Limited engagement of small and marginal farmers in FPO activities.
   - Extension messages may not reach all members, especially in remote areas.

4. **Weak Institutional Linkages**
    - Poor coordination with line departments, KVKs, NGOs, and research institutions.
    - Lack of timely access to expert advice and new technologies.
5. **Governance Issues**
    - Inefficient or politicized management affects trust and transparency.
    - Poor record-keeping and accountability hamper credibility.
6. **Infrastructure and Logistic Gaps**
    - Lack of proper ICT tools, transport, training facilities, and demonstration plots.
    - Difficulty in reaching scattered farmers due to limited mobility.
7. **Resistance to Change**
    - Traditional mindsets and fear of risk delay adoption of innovations.
    - Difficulty in convincing farmers about the benefits of improved technologies.
8. **Diverse Needs and Farm Conditions**
    - Heterogeneity among member farmers (land size, crops, literacy) complicates uniform extension delivery.
    - One-size-fits-all messages often fail to address local needs.
9. **Monitoring and Impact Assessment**
    - Lack of proper mechanisms to evaluate the effectiveness of extension services delivered by FPOs.
    - Difficulty in documenting success stories or best practices.
10. **Policy and Regulatory Gaps**
    - Ambiguity in the role of FPOs as formal extension agents.
    - Limited policy support for capacity building and long-term handholding.

Strategies to Strengthen FPO-based Extension

To enhance the role of Farmer Producer Organizations (FPOs) in agricultural extension, a multifaceted strategy is essential, combining institutional support, capacity building, and innovative approaches. First and foremost, **capacity building programs** must be institutionalized to train FPO staff and leaders in technical agriculture, ICT tools, business planning, and leadership. Collaborations with Krishi Vigyan Kendras (KVKs), State Agricultural Universities (SAUs), and NGOs can provide continuous knowledge and skill enhancement.

Second, **strengthening linkages with research and extension systems** is vital. FPOs should be actively integrated into mainstream agricultural research-extension-farmer (R-E-F) frameworks. Regular interface meetings, field demonstrations, and exposure visits facilitated by expert institutions can promote technology dissemination and build trust.

A third key strategy involves **ensuring financial and infrastructural support**. Dedicated funding under schemes like *Formation and Promotion of 10,000 FPOs*, along with access to credit, insurance, and subsidies, can help FPOs conduct extension activities independently. Infrastructure such as community training halls, demonstration plots, and digital kiosks can further support learning.

Fourth, **promotion of ICT-enabled extension**—like mobile-based advisories, WhatsApp groups, video-based learning, and farmer helplines—can scale the outreach cost-effectively. Tailoring messages in local languages and using audio-visual content can improve understanding among low-literate members.

Fifth, fostering **participatory governance and member engagement** is crucial. Involving farmers in planning, feedback, and decision-making ensures relevance and boosts adoption. Regular meetings, feedback sessions, and grievance redress mechanisms can enhance member ownership.

Additionally, **cluster-based and crop-specific FPO formation** allows more focused extension targeting. Extension strategies should be customized to the local agro-climatic context, cropping patterns, and farmer needs.

Finally, **policy-level interventions** are needed to recognize FPOs as formal partners in the national extension system. This includes capacity development grants, incentives for innovation, monitoring mechanisms, and enabling frameworks to ease access to markets and information.

By adopting a holistic and inclusive approach, FPOs can evolve into dynamic hubs of agricultural knowledge dissemination and farmer empowerment.

Conclusion

Farmer Producer Organizations (FPOs) represent a paradigm shift in agricultural extension by fostering a collective, bottom-up approach to knowledge dissemination and rural empowerment. Unlike traditional models that often treat farmers as passive recipients, FPOs actively engage them as partners in the extension process. Their ability to aggregate demand,

contextualize technologies, and facilitate peer-to-peer learning makes them powerful vehicles for inclusive and sustainable agricultural development. Moreover, FPOs bridge critical gaps in extension by integrating market intelligence, financial services, and institutional linkages.

To fully harness their potential, it is essential to invest in their organizational capacity, ensure convergence with formal extension systems, and enable a supportive policy and financial environment. As India moves toward more decentralized, climate-resilient, and market-driven agricultural systems, FPOs stand out as pivotal agents of change. Strengthening them is not merely an institutional innovation—it is a strategic necessity for building resilient rural livelihoods and achieving long-term agricultural transformation.

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SOIL CONSERVATION STRATEGIES: UNLOCKING THE POTENTIAL OF AGRONOMIC PRACTICES

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Abstract

Soil conservation is a critical component of sustainable agriculture, especially in the face of increasing environmental challenges. Agronomic measures play a pivotal role in preserving soil health and enhancing its productivity. This article explores various agronomic practices that contribute to soil conservation, including crop rotation, cover cropping, reduced tillage, and agroforestry. By focusing on the strategic use of plants and soil management techniques, these measures not only help in preventing soil erosion but also improve soil fertility, water retention, and biodiversity. The integration of these practices into farming systems can lead to long-term environmental sustainability and increased resilience to climate change. This article emphasizes the importance of adopting agronomic measures as part of a broader soil conservation strategy to ensure the health and productivity of soils for future generations.

Keywords: Conservation, Crop rotation, Erosion, Sustainability

Introduction

Soil conservation in India is crucial due to the widespread issues of soil erosion, degradation, and desertification caused by factors like overuse, deforestation, and erratic weather patterns. With a large portion of the population relying on agriculture, conserving soil ensures sustainable farming practices, increased crop yields, and long-term food security. Soil conservation practices are those farming operations and management strategies conducted with the goal to control soil erosion by preventing or limiting soil particle detachment and transport in water or air. Soil conservation is the practice of protecting soil from erosion and degradation

through a variety of methods and practices. It's a long-term process that aims to maintain soil fertility and productivity, and support the environment and food security. This involves techniques such as crop rotation, contour plowing, and cover cropping, which help reduce erosion, improve soil fertility, and enhance water retention. Effective soil conservation is essential for sustainable agriculture, ecosystem health, and food security.

In general, soil conservation operations can be performed in two ways: non-mechanical (agronomic or biological) and mechanical, which are compatible with crop management and land management, respectively.

Agronomic measures for soil conservation

The methods used for controlling soil erosion through crops or vegetation or agronomic practices are called biological/agronomic measures. These methods are equally efficient for controlling both water and wind erosion. Agronomic measures include contour cultivation, tillage, mulching, strip cropping, intercropping, and other improved dryland practices. Generally, agronomic measures are recommended for mildly sloping areas (less than 2%). The main objectives of agronomic measures include:

- Maximize in-situ rainfall conservation
- Dissipate energy of falling raindrops
- Enhance opportunity time for better intake of water by soil profile

1. **Timely Sowing and Crop Canopy Manipulation**

Most of the erosion occurs during few initial storms after the onset of monsoon when land surface is bare without any crop cover. Hence, sowing of crops as early as possible with the onset of monsoon helps in early establishment of crops, better root and shoot growth and development of canopy cover and minimizing soil erosion. Manipulation of crop geometry to achieve closer spacing within the rows across the slope provides greater resistance to overland flow to reduce erosion losses. Although dense plant population is better from soil and water conservation point of view but it may lead to severe moisture, nutrient and light competition resulting in reduced crop yields.

2. **Contour Farming/cultivation**

It is a system of farming on sloping lands in which ploughing, planting, sowing and intercultural operations are carried out along the contour lines as far as possible. It creates numerous ridges and furrows which help in checking soil losses in humid areas and conserve soil

moisture in low rainfall areas. Contour farming reduces runoff and prevents soil erosion as compared to up-and-down cultivation. Apart from conserving soil and water, it also builds up soil fertility and increases crop yields and reduces soil erosion even in high rainfall areas. The efficiency of contour farming to prevent erosion depends on the intensity of rainfall, soil characteristics and topography of the area. Soils that do not have good drainage are not compatible with this method of erosion control because it saturates quickly and breaks cultivation lines. The optimum slope for contour farming is between 3% and 8%.

3. Strip cropping

Strip cropping is a system of crop production in which long and narrow strips of erosion-resisting crops (close-growing crops) are alternated with strips of erosion-permitting crops (erect-growing crops). The strips are laid across the slope. Strips of close-growing crops reduce the transporting and eroding power of water by forming obstructions to runoff and filtering out the soil from the runoff and retaining it in the field. Erosion-permitting crops are sorghum, maize, millet, and erosion-resisting crops are groundnut, moth bean, horse gram. Recommended strip widths are shown in Table 1.

Table 1: Width of erosion permitting and erosion resisting crops

Slope (%)	Width of crop (m)	
	Resisting	Permitting
Up to 1	9.0	45.0
1-2	6.0	24.0
2-3	4.5	13.5

4. Mulching:

Mulches are any material such as straw, sawdust, leaves, plastic film, loose soil, etc., spread upon the soil surface to protect the soil from the effects of raindrops, soil crusting, evaporation, etc. Mulching improves soil aeration, creates better biological activities and consequently has beneficial effect on the soil fertility. In low rainfall areas mulching helps in conserving moisture in the soil profile while in high rainfall areas, it reduces runoff and soil losses which, in turn, are reflected in higher crop yields.

Types of mulching

Vertical mulching: Crop residues pressed in narrow continuous slots of 5-10 cm width and 20-25 cm depth. The residue is filled up to 5 cm above ground level.

These slots with residues form a ridge across the slope. Thus, it increases infiltration and reduces runoff.

Live mulching: The concept of live mulching is based on the principle of mixed cropping. Fast growing legume is established before or simultaneously along with a widely spaced seasonal grain crop such as maize and returned to soil at the appropriate stage to act as mulch. It performs well if live mulch is non-competitive for light, moisture and nutrients.

5. Vegetative barrier

It is a permanent strip of closely spaced grass grown on contours across the slope. Usually, the grass strip is 1.0 m wide with 4 to 8 lines of grass clumps to provide a dense and sturdy barrier against runoff. vegetative barriers are used in the form of narrow filter strips (also called grass barriers) and filter strips. The grass barriers are narrow strips (approximately 1.2 m wide) of tall, erect, stiff stemmed, native perennial grasses planted on the contours to reduce the sediment yield, retard and disperse the runoff and facilitate benching of the slopes. Examples of vegetative barriers, viz., sambuta (*Saccharum* spp.) - local grass, vetiver/khus (*Vetiveria zizanioides*) and lemon grass (*Cymbopogon citratus*). Vegetative barriers established on contours function as erosion controlling mechanisms with the farming system and also provide other products like fodder, fruits, green manure etc. Vegetative barriers perform following main soil conservation functions:

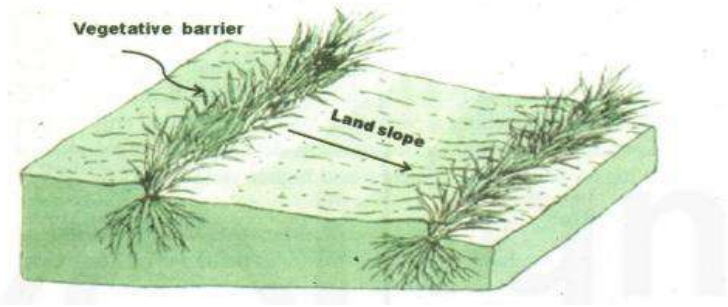


Fig.: Vegetative barriers to control erosion

- Break slope length, reduce runoff velocity and increase infiltration opportunity time.
- Reduce the erosivity and transport capacity of runoff. Arable Lands
- Cause the deposition of eroded material, trap nutrients and induce formation of terracing.
- Cause cultivation and planning operations to be carried out on contours.
- Stabilize contour cultivation areas on steeper slopes.

6. Cover crops:

In agriculture, cover crops are plants that are planted to cover the soil rather than to be harvested. Typical examples of cover crops are legumes like green gram, black gram, cowpea, horse gram, etc. Soil cover must exceed 30% to minimize soil loss. Cover crop roots improve water infiltration by physically loosening soil and building stable soil structure pores and channels.

Benefits of cover crops

- Most effective, easy and economical method
- Provide permanent surface cover between the growing season of main crops
- Protection from soil erosion
- Improvement in soil properties, soil fertility, biological diversity and water quality
- Increase infiltration
- Improve aggregate stability
- Increase soil organic matter content
- Roots and microbial processes provide labile C to contribute to aggregate formation and stabilization

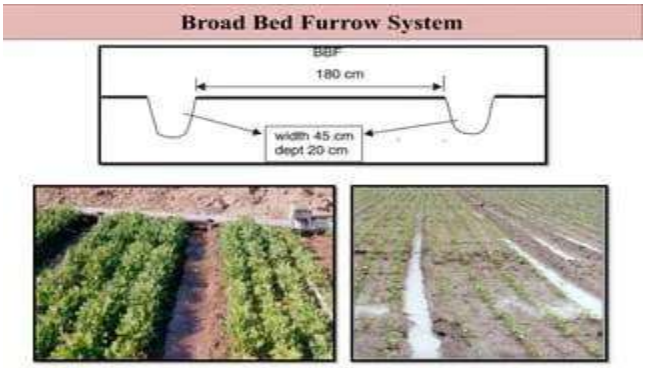
7. Cropping System:

A cropping system is crucial for soil conservation as it helps maintain soil structure, fertility, and overall health. Practices like crop rotation, intercropping, and agroforestry reduce soil erosion and nutrient depletion. For example, rotating legumes like beans or peas with cereals like wheat enhances nitrogen levels naturally, reducing the need for synthetic fertilizers. Cover crops such as clover or rye shield the soil from wind and water erosion while improving organic matter content. These methods foster sustainable land management. Intercropping erosion permitting crops and erosion-resistant crops or their rotation have been found effective for soil and water conservation. As the legumes (cowpea, green gram, black gram) are effective for the conservation of soil due to their fast-growing habit and early cover of the soil with its canopy. In the combination of deep-rooted legumes and shallow-rooted cereals in an intercropping system, legumes create the facility of bio irrigation under limited soil moisture conditions.

8. Broad bed and furrow system

Broad bed and furrow system involves preparation of broad bed of 90-120 cm, furrow of

45 cm and sowing of crop at row spacing of 30 cm. In medium rainfall regions, the broad bed and furrow (BBF) system significantly increased the crop yields, particularly the soybean yields in Vertisols of Maharasthra and Madhya Pradesh upto 83% over the farmer's practice. During high rainfall events BFB drains the runoff through furrows, while also acts storage which moisture availability during scarcity period.



9. Conservation Tillage

The concept of conservation tillage is based on minimum disturbances on the top soil layer by applying practices like reduced tillage, minimum tillage, zero tillage and mulch tillage. Under the conventional tillage, the soil is easily eroded by water and on drying turns into a fine dust by wind. To overcome these ill-effects, tillage operations are reduced and at least 30% crop residue cover is maintained on the soil surface until establishment of crop canopy cover. All the tillage operations should be done along contour, which reduce soil loss from sloping land up to 50% compared to up-and-down cultivation along the slope.

Conclusion

In conclusion, agronomic measures for soil conservation is essential for sustainable land management. Agronomic practices, such as crop rotation and cover cropping, enhance soil health and fertility. These approaches not only protect soil integrity but also promote agricultural productivity and resilience against climate change, ensuring long-term viability for farming systems.

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FERTILE EDGE OF THE NATION: SUSTAINABLE AGRICULTURAL PRACTICES IN KANYAKUMARI

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Abstract

Kanyakumari, the southernmost area of India, is celebrated not as it were for its geological and social noteworthiness but too for its dynamic and assorted rural framework. With a favourable tropical climate, dual monsoon patterns, and fertile soils, the region sustains the cultivation of a wide variety of crops such as paddy, banana, coconut, rubber, and spices. This article examines how Kanyakumari blends traditional farming wisdom with modern innovations to build a resilient and sustainable agricultural economy. It also explores the contributions of women, cooperatives, and agro-based enterprises in strengthening rural livelihoods. Despite ongoing challenges such as climate variability, urban encroachment, and market instability, the district's adaptive approaches and ecological advantages make it a model for future-ready agriculture. As the *Fertile Edge of the Nation*, Kanyakumari offers not just abundant harvests, but also valuable insights, leadership, and inspiration for sustainable farming across India.

Keywords: Dual monsoon agriculture, sustainable agriculture, plantation crops, organic farming, agri-women cooperatives, rubber and banana cultivation.

Introduction

Positioned at the southernmost tip of the Indian subcontinent, Kanyakumari is renowned for its breathtaking coastal landscapes, spiritual heritage, and cultural richness. Beyond its scenic beauty, however, lies a thriving agricultural ecosystem that plays a vital role in the socio-economic fabric of the region. Enriched by a tropical climate, fertile soils, and the unique advantage of receiving both Southwest and Northeast monsoons, Kanyakumari has emerged as

one of Tamil Nadu's most agriculturally dynamic districts. The district's varied topography from coastal plains to the foothills of the Western Ghats supports a wide array of crops, including paddy, banana, coconut, tapioca, rubber, and spices.

What sets Kanyakumari apart is its successful integration of time-honoured agricultural practices with modern scientific methods. Farmers here implement sustainable techniques such as organic farming, integrated cropping systems, and soil-enriching traditional inputs. Simultaneously, the region is witnessing a surge in agri-tech adoption and cooperative models. Women's support through self-help bunches has encourage reinforced this framework, advancing comprehensive development and business strength. As India moves toward climate-resilient and feasible farming, Kanyakumari serves as a signal of advancement established in neighbourhood intelligence.

Agriculture in Kanyakumari

Kanyakumari's landscape is uniquely shaped by its geographic boundaries the Arabian Sea on three sides and the Western Ghats to the north. It encompasses four of the five traditional land types: Kurunchi (hills), Mullai (forest), Marutham (cropland), and Neidhal (coastal). This diverse terrain supports a wide range of crops, from rice in the lowlands to tea and coffee in the higher elevations. The district enjoys the rare benefit of rainfall from both the Southwest and Northeast monsoons.

Covering an area of 1,67,200 hectares, Kanyakumari has a net sown area of 74,712 hectares about 44.6% of its total area. Paddy, the staple food crop, is cultivated in two primary seasons: April–June (Kannipoo) and September–October (Kumpapoo). Pulses such as black gram are grown as rice-fallow crops. Coconut is another dominant crop, extensively cultivated across the district. The soil, ranging in pH from 4.5 to 8.0, supports a variety of crops. The Agricultural Department plays a pivotal role in implementing both central and state-sponsored schemes to promote sustainable development and boost productivity.

Geographical Advantage: Where Nature Favors Farming

Kanyakumari enjoys natural conditions that make it highly suitable for diverse agricultural activities. Nestled between the Western Ghats and the Arabian Sea, the district benefits from abundant annual rainfall exceeding 1400 mm and has rich red loamy, laterite, and alluvial soils. The dual monsoon system extends the growing season, allowing year-round cultivation. Natural irrigation is provided by rivers such as the Pazhayar, Valliyar, and tributaries

of the Tamirabarani. This combination of favourable soil, water, and climate conditions positions Kanyakumari as one of Tamil Nadu's most agriculturally prosperous regions.

Agricultural Diversity: From Grains to Plantations

Kanyakumari's farmers cultivate an impressive variety of crops that reflect the district's ecological richness and adaptability. This diversity not only supports food security but also shields farmers from market fluctuations and climatic stresses. Paddy remains the primary crop, grown under both irrigated and rain-fed conditions. Banana and tapioca serve as staple food sources and commercial crops. Coconut palms are far reaching, supporting businesses such as coir, oil extraction, and delicate coconut exchange. In the uplands, rubber plantations provide a major income source, while spices like pepper and cardamom flourish in the humid, organic-rich hill soils. The district also boasts a strong horticulture and floriculture sector, producing fruits like mango, jackfruit, and pineapple, along with flowers such as jasmine. This agro-biodiversity strengthens both the economy and resilience of the farming community.

Traditional Wisdom Meets Modern Methods

In Kanyakumari, agriculture is marked by the seamless integration of age-old practices with cutting-edge technology. Many farmers continue to use traditional organic inputs like Panchagavya, compost, and green manures to maintain soil fertility and ecological balance. Alongside this, a new generation of farmers is adopting modern techniques such as drip and sprinkler irrigation to conserve water, precision farming through mobile-based tools, and polyhouse cultivation for high-value crops. The soil health card initiative guides the scientific application of fertilizers based on field-specific requirements. This thoughtful blend of tradition and innovation not only enhances productivity but also ensures the long-term sustainability of agricultural resources.

The Economic Backbone: Agriculture and Allied Sectors

Agriculture remains the economic lifeline for a large portion of Kanyakumari's population. Complementing crop cultivation are several allied activities such as sericulture, apiculture, poultry, and dairy farming. These enterprises provide nutritional security and diversify income sources. The district's coastal stretch also supports a vibrant fisheries sector, which works in tandem with inland agriculture. To reduce dependency on raw produce and increase farmers' profits, several cooperatives and farmers' associations have launched small-scale agri-processing units. These units produce goods like banana chips, coconut oil, and spice

powders, adding commercial value to local products. This diversified rural economy illustrates the district's adaptability and enterprise.

Women in Agriculture: Pillars of Productivity

Women in Kanyakumari are key drivers of agricultural progress. They participate in every stage of farming from planting and harvesting to processing and marketing. Women-led Self-Help Groups (SHGs) have taken on leadership roles by establishing seed banks, kitchen gardens, and food processing units. Their involvement has expanded local marketing channels through fairs and exhibitions, allowing them to sell value-added products directly to consumers. This empowerment has led to improved household nutrition, greater educational access for children, and enhanced economic stability. In Kanyakumari, women are not just contributors to agriculture they are architects of rural transformation.

Agro-Tourism and Cultural Linkages

Kanyakumari's stunning natural beauty and rich cultural heritage make it an ideal destination for agro-tourism. Visitors can immerse themselves in rural life by touring organic farms, rubber plantations, and coconut groves. They can also witness traditional farming techniques and join local festivities such as Pongal and Onam, which celebrate seasonal harvests. Agro-tourism offers farmers a valuable supplemental income while promoting environmental awareness and appreciation for sustainable practices. It connects tourists with authentic rural experiences and bridges the gap between agriculture and cultural tourism.

Challenges: Navigating the Future

Despite its many strengths, Kanyakumari's agricultural sector faces significant challenges. Climate change has made rainfall patterns increasingly erratic, and urbanization is steadily reducing arable land. Market price fluctuations and declining interest among youth in agriculture further threaten the sector's long-term viability. Yet, several promising solutions are being implemented. Farmer Producer Organizations (FPOs) are empowering smallholders with better market access and input procurement. Digital agri-tech platforms offer real-time insights on weather and crop management. Government schemes like PM-KISAN, the Agri Infrastructure Fund, and the Sub-Mission on Agricultural Mechanization are improving financial support, infrastructure, and technology adoption. These initiatives are helping farmers become more resilient and future-ready.

Conclusion: A Green Beacon at India's Edge

Kanyakumari, rightfully known as the *Fertile Edge of the Nation*, is a living example of how agriculture can flourish when tradition meets innovation. This southernmost district is a hub of ecological diversity and farming ingenuity, where local knowledge has been skilfully integrated with modern methods to build a resilient agricultural system. Through sustainable practices, community-driven enterprises, and inclusive participation particularly of women, Kanyakumari is not only feeding its people but also preserving its natural heritage. As the world seeks models of climate-resilient, inclusive, and environmentally conscious agriculture, Kanyakumari offers more than just crops it offers a vision for the future of farming, shaped by those who live closest to the land.

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ERI CULTURE-INDIAN SCENARIO

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Introduction

Eri culture refers to the traditional practice of rearing the Eri silkworm (*Samia ricini* or *Philosamia ricini*) for the production of Eri silk, also known as "Ahimsa silk" or "peace silk." Unlike conventional silk production, which involves killing the silkworm inside the cocoon, Eri silk is harvested after the moth has emerged, making it a non-violent and ethical form of silk production. This practice is deeply rooted in the cultural and economic traditions of regions like Northeast India, particularly Assam, as well as parts of Southeast Asia and Africa.

- Eri'- Sanskrit term **"Erranda",** refers to **Castor plant** (*Ricinus communis*)
- Also known as **endi** or **errandi** in India.
- Popular among the backward tribes of **Assam**, especially those of **Indo Mongolian and Tibetan origin**.
- **Poor man's silk in Assam.**
- **Palma Christi Silk**-by Britishers.
- Concentrated mostly on *Philosamia ricini*
- Originated in **India** and its history dates back to **1600 B.C. in Vedic literature.**
- Traded from **Assam to Northern India** as early as **600-650 B.C.**
- Distribution: **Brahmaputra valley in Assam, Northeastern region of India**.
- **CSB** has planned development in AP, Bihar, Jharkand, West Bengal, UP, Punjab, TN, Orissa, MP, Chhatisgarh, Pondicherry, Kerala.

- Major producer countries of castor are **India, China, Brazil, Paraguay, Ethiopia, Philippines, Russia, Thailand**.

Eri silkworms are polyphagous, meaning they feed on a variety of host plants, with castor leaves (*Ricinus communis*) being the most commonly used. The process of Eri culture involves several stages, from egg hatching and larval rearing to cocoon formation and silk extraction. It is a labor-intensive but sustainable practice that provides livelihood opportunities for rural communities, especially women, and contributes to the preservation of traditional knowledge and skills.

Eri silk is highly valued for its soft texture, durability, and thermal properties, making it suitable for a wide range of textiles and handicrafts. In recent years, Eri silk has gained global recognition as an eco-friendly and ethical alternative to conventional silk, aligning with the growing demand for sustainable and cruelty-free products. Eri culture is not just an economic activity but also a cultural heritage that reflects the harmony between humans and nature. It embodies principles of sustainability, ethical production, and community empowerment, making it a vital part of the socio-economic fabric of the regions where it is practiced.

Host plants of Eri Silkworm:

1.Primary host plants:

*Castor- *Ricinus communis*

*Kesseru- *Heteropanax fragrans*

*Payam- *Evodia fraxinifolia*

*Tapioca- *Manihot esculenta*

2.Secondary host plants: Champaca, Jatropha, Barkesseru, Kohra, Papaya, Cinnamomum, Bhotera, Bazraman, Phootkhol, Timur, Masur.

Package of practices of castor cultivation and its management:

The eri silkworm is multivoltine and polyphagous in nature feeding on a number of host plants. Castor (*Ricinus communis)* is the primary food plant of Eri silkworm. For basic seed production and to get the highest potential yield, rearing on castor is must.

Season and climate: The ideal period for plantation is March- April in North Eastern region of India. September-October is another suitable season for raising castor. Castor is a warm season crop. However, it grows under diverse climatic conditions. In winter season (during long dry

spell), its leaf yield gets considerably reduced. It is highly susceptible to water logging condition and hence, drainage is must whenever low-lying area is selected for plantation.

Soil: Flat and sloppy soil either acidic or alkaline is suitable. Water stagnation is to be avoided by adopting proper drainage system in the planting area. However, humus and sandy soil suits for luxurious growth of the plant

Varieties: A non-bloomy red variety of castor, NBR-1 is recommended for eri silkworm rearing in North Eastern region of India. Recently, two more productive accessions Acc 003 and Acc 004 have been developed with more than 13 MT leaf yield/ha/year and later named as NBR-2 and NBR-3. Besides, high oil yielding varieties like Jyothi, GCH-5,

GCH-4, DCH-519, DCH-177, CO1, Aruna etc. are being utilized for eri silkworm rearing in non-traditional states of India among which Jyothi, DCH-519 and DCH-177 showed encouraging performance in Assam condition.

Tillage: Land should be ploughed 2-3 times to a depth of 20-25 cm and leveled for facilitating good root penetration and easy weeding.

Spacing: Pit system of plantation is followed for raising castor for eri silkworm rearing. For sowing of seeds, 20 x 25 x 25cm(Length x Breadth x Depth) size pits are to be prepared maintaining 1x1m spacing. In each pit, 1 kg FYM along with Urea 13 g, SSP 25 g and MOP 3 g are to be added as basal dose and covered with soil. For perennial castor cultivation 1.0x 1.5 m spacing is recommended and pruning at 1m height during March.

Seed collection and treatment: Mature capsule of seeds are to be collected during sunny day. Capsules are to be sun dried well and seeds to be removed. Before sowing the seeds, it is necessary to treat the matured and healthy seeds with Bavistin 2 g / kg to check seed borne diseases.

Sowing: Two seeds per pit at a depth of 2.5–3.0 cm are to be sown. Germination takes place after 7-10 days. Only one healthy seedling per pit is to be allowed for vigorous growth after germination.

Application of fertilizer: In addition to organic manure (FYM), chemical fertilizer is important for better growth and leaf yield in castor. NPK @ 60:40:20 kg /hectare as basal dose at pit or after one month of germination and 30 kg nitrogen/ha as 2nd dose should be applied after attaining the age of three months by ring digging method. In case of fertile land chemical fertilizer may be avoided.

Weeding & inter-culture: A large number of undesirable weeds absorbed nutrients and moisture of soil, resulting stunted growth of castor. Regular weeding helps for luxuriant growth of castor. Besides, ploughing, hoeing, weeding are to be carried out timely after and before application of fertilizer for healthy growth and higher leaf yield.

Harvesting of crop: Four leaf harvests can be made in North East region from a single plant in a year during May-June, July-August, September-October and November-January.

Crop	Leaf yield/acre/year (kg)
May-June	1400
July-August	1200
September-October	1200
November-January	1000

Pest of Host plants: Castor Whitefly, Castor semi looper, Castor semi looper, Red hairy caterpillar, Castor seed and Capsule Borer, Slug caterpillar, Castor slug, Tussock caterpillar, Bihar Hairy Caterpillar, Thrips, Jassids, Castor Leaf Hopper, Castor butterfly, Castor spiny caterpillar, Serpentine leaf miner.

Diseases of host plants: Charcoal Rot Fungus, Seedling blight, Capsule mold, Grey mold, wilt, gray rot, Cercospora leaf spot, Bacterial leaf spot, Bacterial leaf rust, Powdery mildew, Root rot, Cotton root rot

Eri rearing

Biology of Eri Silkworm:

Egg: Ovoid, candid white, measuring 1.5-1mm, weighing 6mg. Moth emerged from lighter pupae deposited less eggs whereas heavier pupae laid more eggs. 400 to 500 eggs were laid by per moth. Maximum no.of eggs laid during September and minimum during June to July. Eggs hatch in 7 to 9.00am.The highest hatching percentage (90.60%) among the first day deposited eggs. Maximum hatching percentage in Aruna (98.94) and RC-8 (99.94) on castor genotypes.

Larva: Newly hatched larvae are greenish yellow in colour measuring about 4*0.7mm and weighing 1.3mg. The body colour changes to pure yellow by end of third day.They are reared in both plains and hilly regions. Prothoracic hood of 1st instar larvae has black dorsal band which splits into a pair of crescent shaped marking during 2nd instar and disappear in 4th instar. Lateral line is creamy white extending along the whole length of the body.

Tubercles are tubular and very conspicuous.They look bluish at the base and creamy at the tip and bear pointed black setae at tip by 3rd instar. Larva are gregarious in second instar and

relatively small heads.In the third and fourth instars, larvae are creamy white with yellow heads and legs.In final instar, larvae begin to look much more like atlas larvae, pale blue-green and covered with fine white powder.There are fleshy protuberances along back and sides.The mature larvae about 8.5cm long and 1.7cm wide and weigh about 6.2g.They produce a very a rustling sound when rolled between fingers and have tendency to move upward and away from the foliage.They search suitable cocooning place on the Chandrika and remain there after discharging larval excreta. After 13 to 15 hours of spinning larvae are invisible.The cocooning is completed in 3 days during summer, in 5 days during winter.

Pupa: Obtect, measures about 2.8*1.5cm and weigh about 2.6g.The pupal duration was 18days in male and 20 days in female.

Cocoon: The cocoons are peduncle less, elongated, soft, wooly, open at one end and unreelable.It measures about 4*2.5 cm and weighs about female 3g and male 2.5 g.The cocoon colour varies between creamy white to reddish brown or brick red. Shell weighs about 0.4gm and constitutes about 13% of total cocoon weight.

Adult: Adult longevity of 5to 6 days in male and 10 to 15 days in female. The body of the male moth measures about 2.5cm and female 3cm with wing span of 13 to 15cm each.The forewing of both sexes is almost similar with brownish, blackish or chocolate colour.The ante median line is of bright chocolate coloue with white border on either side and runs entire centre. Conspicuous black spot, pterostigma, surrounded by whitish tinge around it present at top of apex of the wing.

Rearing House: Eri silkworms are reared indoors. The plinth area of 10 m x 5 m size rearing house having tin or thatch roofing with 1.5 m verandah all around is ideal for accommodating 100 dfls for commercial and 50 dfls for cellular stock maintenance of eri silkworm rearing per crop. The rearing houses are to be built with adequate number of windows for maintenance of a good environment and ventilators which are also to be fitted with nylon nets to stop entry of uzi flies. Efforts should be made to maintain temperature, relative humidity, light and other hygienic conditions inside the rearing house in different seasons. Plantation of evergreen trees around the rearing house should be encouraged for maintaining a better environment. The rearing house should have enough space for leaf preservation, young age and late age silkworm rearing and mounting. It should have the facility for disinfection and cleaning conveniently.

Requirement of rearing appliances: Hand sprayer, Rearing stand (wooden) 2 m x 1.8 m x 0.50 m with 5 shelves, 3Feeding stand (Wooden), Rearing tray (Bamboo), Chandrika (Bamboo),Ant

wells (Aluminum),Disinfection mask, Leaf preservation chamber (Wooden), Egg hatching box (Plastic) , Wash basin , Wash Basin, Hygrometer Digital or wet & dry bulb, thermometer, Basket, Old news paper , Bleaching powder,..

Disinfection and prophylactic measures: Complete and thorough disinfection of rearing house and appliances is vital for successful rearing. In fact, disinfection, before and after each rearing is considered the key for a successful cocoon crop. To protect from pathogens, special attention is needed for disinfection of every nook and corner of the rearing house and appliances with proper chemicals in correct concentration. Disinfection should be carried out on bright sunny days. Some commonly used disinfectants in sericulture are formalin, 26 bleaching powder, lime, sodium hypochlorite and chlorine dioxide. The disinfection with 5 % bleaching powder solution is effective. Sprinkling of 2 % bleaching powder-lime mixture in the surroundings of the rearing house from time to time is good. The room temperature should be maintained at around 25 ˚C during disinfection. All the crevices and holes of the room should be closed to prevent entry of pests, predators, pathogens etc. Windows and ventilators should be kept open for proper aeration and free circulation of air.

Selection of races and season: So far, 25 ecoraces of eri silkworm are characterized collected from different parts of North Eastern region of India, viz., Borduar, Titabar, Khanapara, Mendipathar, Dhanubhanga Kokrajhar, Nongpoh, Diphu, Borpeta, Imphal, Inao, Mukokchung etc. In addition, six strains are isolated and maintained in the germplasm bank of Regional Eri Research Station, Mendipathar in Meghalaya and Central Muga Eri Research and Training Institute, Lahdoigarh. These include yellow – plain, yellow – spotted, yellow – zebra, greenish – blue plain, greenish – blue spotted and greenish – blue zebra. Borduar and Titabar eco-races are better yielder among the ecoraces of North Eastern region of India. The best season for eri silkworm rearing is June-October during which the rearing performance is found better.

Maintenance of environmental conditions during rearing:

Different stages of Eri worms	Summer(minimum days)	Winter (maximum days)
Egg stage	9	18
Larval stage	17	45
Spinning stage	3	6
Pupal stage	13	22
Moth stage	4	6
Total days	46	97

Different stages of Eri worms	Temperature° C	Relative humidity%
Incubation	24-26	85-90
Larval stage	24-26	75-85
Spinning stage	24-25	75-80
Moth emergence	22-24	70-80
Pairing of moths	22-24	70-80

Egg incubation and hatching: Incubation is a process in which the eggs are made to hatch under an ideal temperature, humidity, light, etc. If the process is correctly followed, the rate of hatching and the health of the young worms will be ensured; ultimately the cocoon quality and yield also will be improved. The disease free layings (dfls) of eri silkworms are kept in the egg boxes for hatching. The dfls are kept in the paper boxes or plastic egg hatching box for uniform hatching. Incubation of eggs at optimum conditions of temperature and humidity is essential for uniform embryonic development and good hatching.

Eggs should be incubated in a well-maintained room or incubator at 24-26 ˚C temperature and 80-85 % relative humidity. The colour of the egg changes to a dark bluish before two 28 days of hatching. This is the pigmentation stage and is very sensitive. In this stage, the egg should be kept in total darkness or wrapped with black cloth or paper. It indicates that the eggs are ready to hatch. Eggs should be exposed to light in the early morning hours (6 – 8 AM) on the expected day of hatching to get uniform hatching simultaneously. Eggs generally hatch on 9 to 10th day in summer-autumn seasons and 15 to 20th day in winter. During incubation, the eggs are kept and spread uniformly in a thin layer in the box to facilitate good hatching.

Brushing of worms: Brushing is the transfer of newly hatched larvae from eggs to the rearing bed. The larvae hatch out in the early morning hours and continue up to 9-10 AM. On the first day of hatching, tender leaves are put inside the egg box in the early morning. The newly hatched larvae crawl onto the leaf and start feeding. The leaves along with the larvae are transferred to the rearing tray with new fresh leaves.

The remaining larvae inside the box are gently transferred to the tray with the help of fine and soft brush or bird's feather. The white or creamy colour of the feather or brush is preferred to distinguish the larvae. The worms hatched in the first two days (48 hours) show more healthy, good vigour and growth; and they are considered for stock maintenance of races. However, the worms brushed in first 3 days are generally considered for commercial rearing. Preferably brushing should be completed during the early hours of the day.

Methods of rearing: There are three methods of eri silkworm rearing, i.e., traditional bunch-rearing, improved tray and platform rearing. The farmers of the North Eastern region generally employ bunch rearing method.

Bunch rearing: 10 to 12 leaves are tied together to make a bundle and hung vertically on horizontal bamboo/ wire/ sting support.Then worms are allowed to feed.

Advantages: Simple, easy with minimum cost,yield better due to more hygienic condition.

Disadvatage: More worms cannot be accommodated on bunch and greater space is required for large scale rearing.

2.Tray rearing: Made up of bamboo (round) or wood (square and rectangular). Rearing stand of 6 to 7 tiers system with two trays per time. Bamboo trays of size 1m diameter is more convenient to rear 10 to 15 dfls until 2nd nd 3rd instar: while 600 to 700 worms reared upto 4th instar and 3oo worms in the final instar. More capacity of rearing. The worms can reared in tray upto 3rd instar and later instar reared in bunch feeding .

3.Platform rearing: recommended for mass scale rearing of late age worms. Platform made of wood or bamboo. Ideal size is 5' width and 7' length. 3nos.platform each of 1m*2m size made of bamboo strips with sieve size 1 sq.cm. Maximum of 1200 eri silkworms at 5th instar can reared.By brushing 25 to 30 dfls can reared total 7200 worms.

Feeding frequency:

3 feedings should given per day at regular intervals during chawki rearing. During lateage 5 feedings should given per day.

Instars	Quantity of leaf consumed (g)	Consumption %
1st	30.90	0.28
2nd	127.60	1.16
3rd	492.50	4.48
4th	1330.50	12.12
5th	9008.50	81.96
Total	10,990	100

Bed cleaning: one time in 1st instar, 2times in second instar,three times in 3rd and 4th instar and daily bed cleaning in 5th instar.

Spacing: The maintenance of optimum number of worms per unit area according to the size or stage of the worms during rearing is called spacing of worms. Proper spacing and good aeration keeps the worms healthier. Overcrowding of the worms in the tray leads to competition for food

and space and ultimately undernourishment and unhealthy growth of the larvae often results in crop loss. Optimum spacing is, therefore, to be accomplished through experience. Spacing of the worms should be maintained along with cleaning. Two times rearing space is sufficient from first stage to third stage. In fourth stage, it may be necessary to increase the space by two or three times and again in the fifth stage, two times space is required to increase than the previous stages. In a standard size rearing tray (1.0 m dia), 300 number of fifth stage worms can be reared conveniently.

Handling of moulting worms and care: A good rearing is judged by the uniformity of the larvae entering into moulting and emerging from moulting. The brushing and feeding of the worms play key role for uniform moulting, if handled properly. When worms enter to moult, stops feeding, became lethargic and less motion. If 75-80 % of the worms enter into the moult, there is no need to feed the rest of the worms. But first feeding should be provided when 80 % of the worms emerge out of moult. The worms moult four times during its larval life span. Moulting is a very sensitive period during which the worms cast off its old skin and the body is soft and delicate. The larvae take 12-36 hours to complete the moulting process during the different instars and different seasons. It is important to keep the rearing bed dry when the worms are in moult. No bed cleaning should be done during moult.

Collection and destruction of weak, diseased and undernourished larvae: During rearing, the weak, injured, diseased and irregular worms should be collected immediately and put in 2 per cent formalin solution. Such worms should be buried or burnt carefully to prevent spread of diseases. If rearing continues mixing with these worms, the loss due to contamination and disease spread will be more; even crop failure may take place.

Matured worm collection and mounting: After completion of larval life span, the matured 5th stage larvae discard complete excreta consisting of liquid and semi-solid substances and ready for spinning cocoons. Before spinning, the worms stop feeding and become restlessly moving here and there in search of a suitable place for cocooning. The matured worms produce a hollow sound when it is rubbed gently between fingers. This is the time for picking the ripe worms and putting them on mountages

The commonly used mountages are chandraki, basket filled with dry leaves, jali (a bundle of dry leaves of mango, banana leaves, jack fruit, ornamental plants, etc.) and gunny bag filled with dry leaves. Besided, bamboo chandraki, plastic mountage are also used for cocoon formation.

Recently, for cocooning of eri silkworm ripened worm a simple bamboo strip type mountage has been fabricated. In this mountage good cocoon recovery is 98.9% against 97.43% in conventional jail system and inferior cocoon 1.09% as compared to 2.56% in Jali. Shell weight 0.52g as compared to 0.40 g in jail (Debaraj, et al., 2012). The same has been recently innovated as wooden strip type mountage, which is collapsible in nature. Harvesting of 300 cocoons can be done in 3 minutes in this mountage against 30 minutes in traditional jali.

Harvesting and assessment of cocoons: After completion of spinning, the larval skin is cast off and pupation takes place. The pupa has a thin cuticular skin which is soft and may get ruptured easily, if disturbed. The last and important step is harvesting of cocoons from the mountage in time. Cocoons should be harvested after 5-6 days of spinning in summer and 8-9 days in winter. The harvesting process is the best time of sorting of cocoons according to the quality. The cocoons should be sorted out as good, double, melted, stained, dead, inferior, cut or pierced cocoons. Good commercial cocoons should be shifted and dried perfectly after the harvest. Cocoons should be preserved carefully to protect from fungal infection and attack from pest and predators. Cocoons should be assessed on the basis of cocoon weight, shell weight and silk ratio.

Pest and Disease Control Strategy: Pebrine, Muscardine, Flacherie**,**Grasserie, Parasites and predators (Uzi fly- Exorista sorbillans and rats)

Integrated Disease and Pest Management like spraying uzicide, release of parasitoids, dusting diflurobenzuron or neem derivatives and release of natural enemies.

Present Scenario

Today, Eri culture is practiced in several states in India, including:

1.Assam: Assam is the largest producer of Eri silk in India, accounting for over 70% of the country's total Eri silk production.

2.Meghalaya: Meghalaya is the second-largest producer of Eri silk in India, accounts 40-50% ,with most of the production coming from the Jaintia Hills district.

3.Manipur: Manipur is also a significant producer of Eri silk in India, accounts 10-20%, with most of the production coming from the Imphal Valley.

4. **Nagaland**: Nagaland is another state in India where Eri culture is practiced, accounts 10-20%, particularly in the Dimapur and Kohima districts.

India produces around 1,500-2,000 metric tons of Eri silk every year, with most of it being produced in the northeastern states. The Eri silk production in India is mainly concentrated in the

rural areas, where it provides employment and income to thousands of farmers and artisans. India is a significant contributor to the world's Eri silk production, accounting for **more than 13% of global production.**

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SUSTAINABLE MARINE AQUACULTURE: REGULATORY PRACTICES AND ENVIRONMENTAL SAFEGUARDS

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Introduction

As the global population continues to grow and the demand for seafood escalates, marine aquaculture—also known as mariculture—has emerged as a critical solution to bridge the gap between wild fisheries and consumer needs. Aquaculture currently supplies more than 50% of the seafood consumed globally, and this share is expected to increase. However, the rapid expansion of marine aquaculture has raised significant concerns regarding its sustainability, environmental impacts, and regulatory oversight.

Sustainable marine aquaculture refers to practices that maintain the ecological balance of ocean environments while supporting economic and social benefits. Central to this sustainability are regulatory practices and environmental safeguards designed to prevent degradation of marine ecosystems. This article explores the current regulatory frameworks governing marine aquaculture, highlights key environmental safeguards, and discusses the ongoing challenges and innovations that shape a more sustainable aquaculture industry.

Regulatory Frameworks for Marine Aquaculture

International Governance

At the international level, several organizations provide guidance for sustainable aquaculture. The Food and Agriculture Organization (FAO) of the United Nations has developed the Code of Conduct for Responsible Fisheries, which includes provisions for aquaculture development. It emphasizes the need for integrated coastal zone management, ecosystem protection, and the responsible use of resources.

Additionally, Regional Fisheries Management Organizations (RFMOs) and multilateral agreements like the Convention on Biological Diversity (CBD) influence national policies by encouraging biodiversity conservation and sustainable practices.

National and Regional Regulations

National governments play a crucial role in implementing and enforcing aquaculture regulations. In the United States, for example, marine aquaculture is regulated by a complex network of federal and state agencies. The National Oceanic and Atmospheric Administration (NOAA) leads the coordination of aquaculture policy, supported by agencies like the Environmental Protection Agency (EPA) and the U.S. Army Corps of Engineers.

In the European Union, aquaculture development must comply with the Common Fisheries Policy (CFP) and the Marine Strategy Framework Directive, which ensure that marine activities do not compromise ecosystem health.



Figure 1: Sustainable aquaculture practices (cage culture)

Countries like Norway and Canada, which are major players in the global aquaculture market, have also developed rigorous permitting systems and environmental assessment procedures that monitor fish health, water quality, and site-specific ecological risks.

Environmental Safeguards in Practice

Site Selection and Spatial Planning

One of the most effective safeguards is the strategic selection of farming sites. Marine spatial planning (MSP) helps avoid conflicts with other ocean uses (e.g., fishing, shipping,

tourism) and ensures that aquaculture operations are situated in areas with strong water currents to reduce pollution buildup.

Geographic Information Systems (GIS) and environmental impact assessments (EIAs) are commonly used tools in identifying suitable sites while minimizing harm to sensitive habitats such as coral reefs, mangroves, and seagrass beds.

Effluent Management and Pollution Control

Excess nutrients, organic waste, and chemicals from fish farms can lead to eutrophication, hypoxia, and harmful algal blooms. To mitigate these risks, regulations often require effluent treatment systems, water quality monitoring, and the adoption of low-pollution feed.

Innovative technologies such as Integrated Multi-Trophic Aquaculture (IMTA) are gaining traction. IMTA systems combine species like finfish, shellfish, and seaweeds, which recycle nutrients and reduce overall environmental impact.

Disease and Genetic Containment

Disease outbreaks in aquaculture systems can spread to wild populations and devastate entire ecosystems. Biosecurity protocols, including quarantine measures, vaccination programs, and regular health inspections, are critical components of responsible aquaculture.

Similarly, the escape of farmed species—especially genetically modified or non-native fish—can threaten local biodiversity and gene pools. Enclosures must meet stringent engineering standards, and regulations may prohibit or limit the use of genetically engineered organisms in open-ocean systems.

Antibiotics and Chemical Use

Antibiotic resistance and chemical residues are growing concerns in aquaculture. Sustainable practices emphasize reducing or eliminating the prophylactic use of antibiotics and transitioning toward alternative disease management strategies like probiotics, vaccines, and selective breeding for disease-resistant strains.

Environmental certifications like those from the Aquaculture Stewardship Council (ASC) or Global G.A.P. provide guidelines on responsible chemical use and transparency in farming operations.

Challenges and Future Directions

1. **Climate Change and Ocean Health**

   Climate change adds a layer of complexity to sustainable aquaculture. Ocean acidification, warming waters, and extreme weather events affect species viability and farm infrastructure. Adaptive measures include shifting to more resilient species, improving system flexibility, and investing in offshore and closed-loop (recirculating) systems.

2. **Data Gaps and Enforcement Limitations**

   Many regions still lack comprehensive monitoring systems, and enforcement of existing regulations is uneven. This gap can lead to illegal or poorly managed operations, undermining broader sustainability goals. Enhanced satellite surveillance, blockchain-based traceability, and citizen science initiatives are potential tools to improve compliance and transparency.

3. **Stakeholder Engagement and Equity**

   Effective regulation requires not only scientific and technological input but also the participation of local communities, indigenous groups, and small-scale farmers. Inclusive decision-making processes help align aquaculture development with socio-economic goals and minimize conflicts over marine space and resources.

Conclusion

Marine aquaculture holds immense potential to contribute to global food security and economic development, but its long-term success depends on the rigorous implementation of regulatory practices and environmental safeguards. International collaboration, national policy coherence, and local stakeholder involvement are all essential to shaping a sustainable mariculture industry. As technology advances and environmental awareness grows, the aquaculture sector must continue to innovate while adhering to principles of ecological integrity, social responsibility, and economic viability. With robust governance and science-based safeguards, marine aquaculture can evolve into a truly sustainable pillar of the global food system.

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MANAGEMENT OF CROP RESIDUE

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Introduction

Over a period of time, traditional practices of agriculture, especially burning of crop residue, are exerting excessive pressure on natural resources and environment which is having several serious effects. Crop residue burning has adverse impacts on soil, air and health of the society. There are losses in soil nutrients, soil organic matter, production and soil fertility. Emission of smoke which when added to the gases present in the air like methane, nitrogen oxide and ammonia can cause severe atmospheric pollution and increase the incidence of road accidents. These gaseous emissions can pose health risks to both humans and animals. It aggravates asthma, chronic bronchitis and decreased lung function. Burning of crop stubble has severe adverse impacts especially for those people suffering from respiratory disease, cardiovascular disease, pregnant women and small children.

Crop residues are nutrient rich resources of tremendous value that increase soil fertility. Nitrogen, phosphorus, sulphur and potassium uptake by different crops are retained in residues, making them valuable sources of nutrients. However, a large portion of the crop residue is burnt in fields primarily for easy and cost effective clearing of fields after the harvest which leads to soil and air pollution. The deteriorating environmental health makes it vital to find the possible solutions for the efficient utilisation and management of crop residue.

Generation of crop residue

The estimates of Ministry of New and Renewable Energy, Government of India brought out that India produces about 500 million tons (MT) of crop residue annually. The generation

and use of crop residue varies along different states of India depending upon the cropping intensity, productivity and cropping pattern in different states. Among different crops, cereals generate 352 MT residue, followed by fibres (66 MT), oilseeds (29 MT), pulses (13 MT) and sugarcane (12 MT). The cereal crops (rice, wheat, maize, millets, bajra) contribute around 70 per cent of the total crop residue while rice crop alone contributes nearly 34 per cent. Wheat ranks second with 22 per cent of residue whereas cotton contribute about 11 per cent of residue generated from all crops. Residue generation was found to be the highest in the state of Uttar Pradesh (60 MT) followed by Punjab (51 MT) and Maharashtra (46 MT). Estimated total crop residue surplus in India is about 141 MT per year and about 59 per cent of the surplus residue is burnt in our country.

The total crop residue generated in Punjab state was estimated around 46551 thousand tons, out of which maximum contribution was made by paddy (49%) followed by wheat (42%), cotton (5%), maize (2%) and other crops (2%). Out of the total residue generated from different crops, about 71 per cent is mostly used for different purposes like fodder, fuel wood, thatching, manuring, etc. and about 29 per cent remained surplus which is mostly burnt in the fields. According to another study by the Punjab government relating to use of crop stubble by the farmers, it was found that a large proportion, (81%) of the rice stubble is burnt in the fields to get rid of the residue, only 7 per cent is used as fodder and for other miscellaneous purposes, 4 per cent is used for rope making and only 1 per cent is incorporated in the soil. Similarly, for wheat crop, the major proportion of the total stubble production (48%) is burnt, however, 45 per cent is used as fodder, 7 per cent is used for miscellaneous purposes and less than one per cent is incorporated in soil.

Steps to be taken for crop residue management

In spite of various efforts made by the government to protect environment from pollution, one of the major steps is to stop crop residue burning. It has been noticed that shortage of labour, higher wage rates at the time of harvesting, ease of harvesting and threshing with combine, uncertainty of weather, cost cutting and time saving are some of the reasons behind mechanized harvesting. Such technology leads to ample generation of residue as large amount of the residues after the combine harvesting is left in the field as loose straw. Burning of crop residue in fields has become a standard method of crop residue management because the fields can be cleared easily for the sowing of next crop. Because of additional costs involved in collection of crop

residues along with lack of knowledge for efficient utilisation of these residues, farmers are forced to burn them in the field. The residues can be put to various uses if collected and managed properly.

- There are innovative machines available, like the chopper and the shredder machine that can be attached with the combines which further facilitates conservation of residue as residue get mixed with soil and later the fields can be cultivated with traditional drill for sowing of wheat crop. Despite the subsidies given by the government for such equipment they are not being much used. There is a need to educate the farmers about the use and benefits of such machinery.
- The desired machinery which assists in conservation agricultural practices such as Happy Seeder, bailer, etc. should be made available at village level co-operatives and further steps should be taken to ensure their timely availability to the farmers.
- The crop residue of paddy can be tilled and put to use directly without uprooting it with the help of Happy Seeder which not only plants the wheat seeds but also helps in mixing the residue in the soil. Such improved technology not only eases the seeding process and mixing of crop residue in soil but also reduces the chances of weeds in the wheat crop.
- Establishing of self-help groups can encourage taking up of custom hiring of machinery for conservation of agriculture as a profession by the unemployed youth.
- The crop residue can be used to prepare compost by spreading it as animal bedding which can later be used as manure which further enhances crop productivity. Farmers should be encouraged to adopt this practice on a large scale.
- The crop residue can also be used for mushroom cultivation which is a good source of nutrients in human diet.
- Biomass such as rice straw can be converted to biogas and used as domestic fuel. This process promises a method to utilize crop residues to extract high quality fuel gas.
- Crop residues should be classified as amendments (like lime or gypsum) and their use in agriculture should attract subsidy like any other mineral fertilizers. This would stimulate the use of crop residues in various production systems.
- There is a potential for power generation from the agriculture biomass in Punjab state and hence, energy plantations should be encouraged to utilize the surplus biomass for energy

generation in a sustainable, environment friendly and cost effective way.

- Also, the residue acts as an important raw material for industries as it can be used for packing.
- The paddy residue helps in making phospho-compost which is rich in phosphorus.
- Burning of crop residue which is widely practiced in Punjab needs to be stopped in order to ensure healthy fertile soil and pollution free environment. Monitoring and discouraging burning of crop residue through new punitive laws should be implemented.
- There is a need to create awareness among the farmers about the importance and efficient utilisation of crop residues through demonstrations for ensuring progressive agricultural sector.

Conclusion

Despite policy efforts, farmers continue to cultivate paddy and burn stubble due to poor incentives, ineffective procurement mechanisms, and structural challenges in the agriculture-water-air nexus. They are not villains but victims of a broken system. Farmers grow paddy primarily because of assured procurement and higher returns, unlike other crops. MSP (Minimum Support Price) is declared for other crops (like pulses), but actual procurement is weak or absent, making them riskier choices. This distorts cropping patterns, leading to monoculture and resource overuse. Managing paddy residue (straw) is a major challenge post-harvest. Farmers have options like manual labour, mechanisation (e.g., Happy Seeder), or burning. Cash incentives are preferred over subsidies for machines because machines are expensive even with subsidies and operational costs and ease-of-use matter more than ownership. The Agriculture-Water-Air Nexus is the major issue as the agricultural choices affect water usage, which in turn affects when and how crops are harvested. Delayed sowing leads to narrow harvest windows, forcing fast clearing of fields before the next sowing. It is important to understand that the farmers are not willingly polluting — they are constrained by economics, policy, and timing. They face an unfair trade-off between environmental responsibility and livelihood and the system has left them with no viable alternatives in the short term. To genuinely reduce stubble burning and encourage crop diversification, the government must strengthen procurement for alternative crops, provide direct cash support for sustainable practices and address the broader policy misalignments in water use, crop choice, and air quality regulations.

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IMPORTANCE OF NORTH CAROLINA DESIGNS IN PLANT BREEDING

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Introduction

The nature and magnitude of genetic variances (additive, dominance and epistasis) determine the breeding strategy for crop improvement. These magnitudes can be ascertained by testing the performance of crossed progenies derived from the chosen parents against a common genetic background. The estimated components determine the genetic potential of the parents as they relate to the parents involved in the crossing but not to the progenies derived from them. The components of genetic variance can be obtained with the help of covariances between the progenies namely full-sibs, half-sibs or parent-progeny descendants. These progenies are developed by following a definite crossing pattern *ie*., mating design. Several mating designs are being utilized to extract the maximum genetic information from the material under study.

Cockerham (1963) classified mating designs as one, two, three and four factor designs based on the control on the number of ancestors per progeny. Comstock and Robinson (1948, 1952) has proposed three designs known as North Carolina Designs *viz*., NCD I, NCD II and NCD III. These are two factor designs as there is control on the two parents involved in the development of the progeny. Hence also known as biparental mating designs. Each of these designs provides estimates for two important genetic parameters, additive genetic variance and dominance variance which tend to define the breeding strategy for crop improvement. The base population for producing the experimental material for these three designs is F_2 generation or any advanced generation maintained by random mating of a cross between two inbred lines. In all

these designs full and half sib progenies are produced by attempting biparental matings in F_2 generation. These were developed to measure the average degree of dominance involved in the action of genes governing the inheritance of quantitative characters. Analysis of these designs involves both first and second order statistics as it utilizes means, variances and covariances.

Assumptions: For valid inferences from NCD's, the following assumptions should be fulfilled.

- Random distribution of genotypes relative to the variations in the environment
- Random choice of individuals from F_2 population which are mated to produce experimental progeny
- Absence of non-genetic maternal effects
- Regular diploid behaviour of the chromosomes at meiosis
- Gene frequency in the population should be one-half at all the loci (p=q=0.5)
- Lack of multiple alleles. Multiple alleles bias the estimates of components of genotypic variance
- Absence of linkage. In presence of linkage, the repulsion and coupling phase linkages should be in equilibrium
- Absence of non-allelic interaction (Epistasis)

North Carolina Design I (NCD I)

In NCD I design individual plants are randomly selected from the base population (F_2). Four randomly selected female plants are mated to a single randomly selected male plant. This is known as one male group which is polygamous in nature as one male is mated with four different females. So that a set of four full sib families are produced per each male group and progeny families of a given male are half sibs.

Mating pattern for one set

SET I			
m_1	x f_1	m_3	x f_9
	x f_2		x f_{10}
	x f_3		x f_{11}
	x f_4		x f_{12}
m_2	x f_5	m_4	x f_{13}
	x f_6		x f_{14}
	x f_7		x f_{15}
	x f_8		x f_{16}

Analysis of variance (ANOVA) for NCD I

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	Expected variances
Sets	s-1	SSS	SMSS	
Replications in set	s(r-1)	RSS	RMSS	
Males in sets	s(m-1)	MSS	MMSS	$\sigma^2_e+r\ \sigma^2_f+rf\sigma^2_m$
Females in males in sets	sm(f-1)	FSS	FMSS	$\sigma^2_e+r\ \sigma^2_f$
Error	s(mf-1) (r-1)	ESS	EMSS	σ^2_e

- Variance among the males [(1/4) σ^2_A] is an estimate of additive variance
- Variance among the females [(1/4) σ^2_A + (1/4) σ^2_D] is an estimate of additive and dominant variance

Similarly large number of male groups can be produced. A female parent crossed with a male parent shall not be involved in mating with other male parent. Four male groups form one set. So one set contains four males and 16 females. Different sets are made up of different male groups. This is a system of hierarchical classification. The number of crosses is equal to the total number females in all the sets. The plot size requirements of NCD I is 10-12 times larger than that of NCD III.

North Carolina Design II (NCD II)

NCD II is a modified form of NCD I to make it suitable for multiflowered/tillering plant species such that one female is crossed with four males. It is a polyandrous design as one female is crossed with more than one male. In NCD II the experimental material is produced by mating between all the randomly selected ‘m’ male plants with the ‘f’ female plants. Thus the total number of crosses are ‘mf’. This system is a case of cross combination. The plot size requirement is intermediate as it is 2-4 times larger than that needed for NCD III. This design consists of full sibs and both paternal and maternal half sibs. So the variation is divided into two parts, between full sib families and within full sib families. The variation between families is further divided into components due to differences among males, females and due to male x

female interaction. In topcross or L x T designs only one set of progenies are developed, while in NCD I or II or III more than one sets are developed.

Mating pattern

Male parents	Female parents			
	f_1	f_2	f_3	f_4
m_1	x	x	x	x
m_2	x	x	x	x
m_3	x	x	x	x
m_4	x	x	x	x
m_5	x	x	x	x

Analysis of variance (ANOVA) for NCD II

Source of variation	Degrees of freedom	Sum of squares	Mean sum of squares	Expected variances
Sets	s-1	SSS	SMSS	
Replications in sets	s(r-1)	RSS	RMSS	
Males in sets	s(m-1)	MSS	MMSS	$\sigma^2_e+r\ \sigma^2_{mxf}+rf\sigma^2_m$
Females in sets	s(f-1)	FSS	FMSS	$\sigma^2_e+r\ \sigma^2_{mxf}+rm\sigma^2_m$
Males x Females in sets	s(m-1) (f-1)	MFSS	MFMSS	$\sigma^2_e+r\ \sigma^2_{mxf}$
Error	s(mf-1) (r-1)	ESS	EMSS	σ^2_e

- Variance due to males and females [(1/4) σ^2_A] is an estimate of additive variance
- Variance due to males x females [(1/4) σ^2_D] is an estimate of dominant variance

North Carolina Design III (NCD III)

The experimental material for estimation of genetic parameters in NCD III is produced by back crossing the randomly selected F_2 plants (as males) with the two inbred lines (as females) that are involved in the development of F_2 population, so that each male will be mated with the same two female parents. The number of crosses are equal to 2n (n=number of randomly selected male parents). Among the three north carolina designs, NCD III is most

powerful as it eliminate effects of linkage due to backcrossing and provides precise estimates of average degree of dominance and additive variance components.

Mating pattern

Males	P_1	P_2	Males	P_1	P_2
Set I			Set III		
m_1	x	x	m_9	x	x
m_2	x	x	m_{10}	x	x
m_3	x	x	m_{11}	x	x
m_4	x	x	m_{12}	x	x
Set II			Set IV		
m_5	x	x	m_{13}	x	x
m_6	x	x	m_{14}	x	x
m_7	x	x	m_{15}	x	x
m_8	x	x	m_{16}	x	x

Analysis of variance (ANOVA) for NCD III

Source of variation	**Degrees of freedom**	**Sum of squares**	**Mean sum of squares**	**Expected variances**
Sets	s-1	SSS	SMSS	
Replications in set	s(r-1)	RSS	RMSS	
Males in sets	s(n-1)	MSS	MMSS	$\sigma^2_e+2r\sigma^2_m$
Females in sets	s	FSS	FMSS	
Interaction in sets	s(n-1)	ISS	IMSS	$\sigma^2_e+r\ \sigma^2_m$
Error	s(2n-1) (r-1)	ESS	EMSS	σ^2_e

- Variance among the males [(1/4) σ^2_A] is an estimate of additive variance
- Variance due to interaction [(1/2) σ^2_D] is an estimate of dominant variance

Merits of North Carolina Designs

- Provide information about two components of genetic variances, *viz*., additive and dominant variances

- Effective in breaking undesirable linkages as it is involved in the mating between randomly selected plants in the segregating generation.
- Helps in the identification suitable breeding method for genetic improvement of various characters
- Applicable for both self and cross pollinated crops

Demerits of North Carolina Designs

- Does not provide information regarding non-allelic interactions
- Based on the various genetic assumptions, which are seldom fulfilled
- Analysis is difficult than the generation mean analysis

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PHYTOREMEDIATION FOR CONTAMINATED SOILS

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Abstract

A green technology called phytoremediation cleans contaminated soils, sediments, and waterways by utilizing the inherent qualities of plants. It's an economical and environmentally responsible substitute for conventional techniques. Depending on the species and remediation technique, plants can absorb, stabilize, decompose, or volatilize a variety of environmental toxins. The mechanisms of phytoremediation have been clarified by research, and plant tolerance has increased as a result of biotechnology developments like genetic modification. Its drawbacks include difficulties disposing of biomass and slow cleanup rates.This review explores these mechanisms in depth and evaluates recent scientific efforts aimed at overcoming existing barriers to wider application.

Keywords:

Phytoremediation, contaminated soils, phytoextraction, phytostabilization, plant microbe interactions, rhizodegradation

Introduction

Ecosystems and public health are seriously threatened by organic pollutants and heavy metal contamination of the environment. Conventional remediation methods, such as chemical treatment and excavation, are frequently expensive, disruptive, and unsustainable. In response, phytoremediation has emerged as a promising green alternative. This technology employs plants to extract, stabilize, degrade, or volatilize contaminants, offering a cost-effective and visually appealing solution with minimal ecosystem disturbance (Salt et al., 1998).

Phytoremediation Mechanisms

Phytoremediation operates through several interrelated mechanisms. These are commonly categorized into phytoextraction, phytostabilization, phytovolatilization, rhizodegradation/phytostimulation and rhizofiltration (MDPI, 2021; Springer, 2021).

Phytoextraction

Also known as phytoaccumulation, this process involves the uptake of contaminants via roots followed by translocation and concentration in harvestable aerial tissues. It relies on hyperaccumulator species, which can store metals at concentrations up to 100–1,000 times higher than standard plants, without showing phytotoxic effects (Discover Applied Sciences, 2021). For instance, Brassica juncea (Indian mustard) effectively accumulates cadmium and has been explored in both greenhouse and field studies (Aoun, 2008). Uptake starts with metal attaching to the root cell walls. This is followed by active transport into the symplastic pathway using specific membrane transport proteins like ZIP, NRAMP, CDF, and ABC transporters. After the transport through the xylem, chelation agents such as phytochelatins or organic acids store metals in vacuoles or cell walls in the shoots. (Springer & MDPI, 2021).

Phytostabilization

This mechanism immobilizes contaminants in the soil or root zone, preventing leaching and exposure risks. Plant roots stabilize metals by sorption, precipitation, and complexation. Mycorrhizal associations also help bind contaminants and reduce their bioavailability. (Frontiersin, 2020; Encyclopedia MDPI, 2021). This is particularly useful for metals in mine tailings or landfill settings, though it does not remove pollutants from the site.

Phytovolatilization

In phytovolatilization, plants uptake contaminants and metabolize them into volatile forms, which are then released to the atmosphere. Elements like selenium and mercury are often removed in this way using plants such as Brassica, poplar, or transgenic Indian mustard.(Wired, 2005; MDPI, 2021). While this reduces soil contamination, it does raise concerns about redistributing materials in the atmosphere.

Rhizodegradation/Phytostimulation

Also called phytostimulation, this involves root exudation that helps rhizosphere microbial communities break down organic contaminants like petroleum hydrocarbons, PCBs, PAHs, and pesticides. Roots release compounds, including organic acids, amino acids, sugars,

phytohormones, and enzymes such as phosphatases. These compounds promote microbial degradation in the soil. (Encyclopedia MDPI, 2021).

Rhizofiltration

This method targets water conditions by taking up dissolved pollutants at the plant root level. While this technology is used mainly in water treatment systems, it can be used with contaminated soils that result in saturated conditions. Sunflowers, Indian mustard, and poplar roots have been used to uptake heavy metals from leachate and runoff.

Plant–Microbe Interactions

Mycorrhizal fungi extend the plant's root absorption surface, producing organic acids and enzymes to enhance metal uptake or immobilization. Arbuscular mycorrhizal fungi can both sequester metals in fungal tissues and modulate host plant transporter gene expression, influencing root-to-shoot translocation (Frontiersin, 2020).

Enhancing Phytoremediation Efficiency

To overcome limitations of conventional phytoremediation, researchers are integrating agronomic and biotechnological tactics:

Agronomic Interventions

Amending soils with chelators (e.g. EDTA, biodegradable EDDS), organic matter, and fertilizers can significantly increase metal bioavailability and plant uptake (MDPI, 2021; Openscience, 2023). However, non-biodegradable chelators may pose environmental risks, pushing a shift toward eco-friendly alternatives such as EDDS.

Genetic and Biotechnological Approaches

Genetic engineering and gene editing hold immense promise. Transgenic Indian mustard with bacterial genes has shown a 430% increase in selenium uptake (Wired, 2005). CRISPR-Cas9 has been applied to improve metal accumulation and tolerance in plants such as wheat and Arabidopsis.(MDPI, 2022). In addition, the application of mercuric ion-binding proteins, metallothioneins, and nitroreductases by transgenesis has enhanced the degradation of organic pollutants such as TNT and mercury (MDPI, 2021).

Discussion and Challenges

Although there are still a number of obstacles to overcome, phytoremediation provides a comprehensive and sustainable remediation solution. Contaminant, plant species, soil conditions (pH, organic matter), and climate all affect efficacy. Pollutants are only immobilized by

phytostabilization; they are not completely removed. Redistributing pollutants into the atmosphere is a risk associated with phytovolatilization. Another issue is the disposal of contaminated biomass, which frequently calls for phytomining or incineration. Furthermore, there are ecological and regulatory concerns with the introduction of genetically modified organisms. Despite these hurdles, advances in biotechnology, agronomy, and microbial symbiosis are improving yield, speed, and applicability of phytoremediation in diverse environments. Field-scale implementations are becoming more frequent, suggesting commercial feasibility in select cases (Acharya et al., 2023).

Conclusion

For the remediation of contaminated soils, phytoremediation provides a practical and sustainable substitute. This green technology is developing quickly through a combination of uptake, immobilization, degradation, and volatilization, aided by advanced genetic enhancement and plant–microbe synergy. However for a useful and secure implementation, site-specific planning, ongoing observation, and integrative management are still necessary.

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COMPARISON BETWEEN FRESH WATER MARINE WATER FISH SEED COLLECTIONS TECHNIQUES

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Abstract

The collection of fish feed is a critical component in aquaculture and fisheries management. This study represents analysis of fresh water and marine water fish seed collection techniques highlighting the methods of collection. Fresh water seed collection primarily depends/relies on riverine system utilizes simple gears and benefiting from controlled environment

Introduction

Fish seed is the primary pre-requisite to develop the fish culture in India. Indian major carps are preferred for cultivation in fresh water ponds and tanks throughout the country. Natural habitat of the IMC is reverse and their original spawning grounds are the flooded rivers. Since long time traditional methods of spawn and fry collection from those natural resources built up particularly in Bengal which soon spreads to other stated of eastern India. Attempts were made to standardize these spawn collection nets to evolve Comparison between fresh water marine water fish seed collections techniques methods of collection and to as certain factors responsible for fluctuations in the availability of fish seed in relation to time and speed.

Fish seed collection in marine Environment

1.Techniques and Gears

Stationery gears: The nets having fine mesh size <1mm like “Min Tana Jal” used for collection of tiger prawn (Penaeus monodon) seeds from Indian sunderabans. It results in by catch of fish juvenile.

a. Light attraction:Macrobrachium rosenbergii species post-larvae (or) gravid female migrates to estuaries/lagoons for spawning are collected using scine nets at night, explotting their photolactic behaviour.
b. Artificial shelters: Palm (or) coconut branches placed in lagoon acts as trap for post-larvae.Later retrieved with fine mesh nets.
c. Plankton net: Used to collect larvae ,eggs from surface water
d. Bagnet/Stakenet:Operated in estuarine and coastal areas to collect the juvenile fish.
e. Tidal traps & Enclosures: Utilized in mangroves & estuarine region to trap fish seed.

1. Species-specific collection periods

- Milkfish (Chanos chanos): Peak seed availability from March to June in coastal areas .Fry season from October -December.
- Mullet (Mugil species): Collected mainly throughout the year with peak abundance from October-February.
- Seabass (Lates calcarifer): Juveniles collected during the monsoon months(March-May).
- Grouper's snapper: Fry availability aligns with spawning cycle often region dependent.
- Tiger prawn: Seed collection in sunderabans peaks April-September coinciding with monsoon driven estuarine conditions.

Regional examples:

a. In Philippines: Milk fish fry collected by nets & traps.
b. In sunderabans, India: 95% of locals engage in prawn seed collection, but non-target species like mugil cephalus, lates calcarifer are discarded biodiversity.
c. Indonesia & Philipines: Traditional fish corals used for milkfish fry and grouper fry.
d. Krishna & West Godavari districts, AP: Fishermen use scape and drag nets in mangrove & estuaries .Collection is mainly practiced from March-May for Asian Seabass, March to July for milkfish & year round for mullet.
e. Ganga riverine system: India spawn collection is prevalent in Bihar with major collection enters along the ganga, Yamuna & Brahmaputra rivers.

f. Assam, Brahmaputra river system: Natural fish seed resume are found in Brahmaputra through quality vares.

Fish seed collection in Fresh water

1. ***Gears & methods:***

a. Riverine collections:

- Funnel shaped "shooting net" are deplayed in river bonds where centrifugal force push spawn towards bands.
- It is operated in the shallow margins of flooded rivers.
- Bunchi ,Jal is used to collect seed in west Bengal. Especially in the south-west part of Bengal for seed collection Midnapur net is used.
- **Bundh breeding** :Seasonal ponds mimic natural flood condition to induce carp spawning widely practiced in India.
- The shallow areas of bundh where fishes actually spawn are called Mexicans.
- Basket traps are used to collect fry and fingerlings from river Godavari.

Unique natural source:

Rivers are the most unique & significant natural source for freshwater fish seed especially during monsoon flooding major riverine system such as the Ganga ,Brahmaputra & Indus in northern india as well as major peninsula rivers like Godavari ,Krishna & Kaveri serves as the primary natural habitats where fish breeds spawn naturally.

- ***These flooded rivers have ideal conditions for spawning of Indian major carps.***

Seed Transports Handling

- Conditioning prepares fish seedlings to newer environment where they will be maintained at higher density. Rough handling of fish seedling may cause damage. During conditioning no feed provide to keep the gut of fish seedlings empty reduce metabolic activity & minimize addition of Nitrogen was into transport water & mortality of seeds.
- Conditioning is done by keeping them in hapa inside the source for 10hours to 2days.

Grading:

- Fish seeds grading done as per size mainly used to reduce the disturbance due ti inter-species sizes during transport and post stocking.

- Usually catfish are hardy species are amensable for transport in higher densities with minimum oxygen pressure.
- Order for hardiness of fish species is catla>mrigal>rohu>grass carp>silver carp.
- Fish seedlings are dipped in 1-2 ppm of KMnO4 before transport for disinfection.
- Add NaCl or CaCl2 to the transport H2O to reduce the handling stress & later stage mortality.
- Use plastic bags of 15-25Kg capacity with 65-75cm-L/40-45cm-b & 30-50 microns thickness have moderate softness ,flexibility for better handling.
- Closed system: Polythene bags filled with 6-7L water & 4L O2 transport of 20k-40khatchery/bag.
- Open system: Galvanized Fe drums (180L) & canvas tanks (1cm3) with aeration are used for breeders & large fingerlings.

Modern techniques & Innovations

a. Modern bundles: Are engineered for best H2O management broodstock handling & seed harvesting reducing the collection of unwanted species improve seed quality.
b. Scientific site selections: Use of trial nets and systematic surveys to identify optimal location & timing for seed collection maximize yield & minimize by catch of have target species.
c. Improved nets: The use of specialized nets (Eg;fixed purse nets ,set bag nets ,like be hundi jal ,bendijal ,badhajaL ,saver) designed for minimal damage to fry & selective harvesting of desired species.
d. Genetic improvement: Programs like G-3 initiative rohu in Bangladesh integrate improved broodstock and advanced genetic into seed production ensuring better growth rates & disease resistance.

Challenges in fish seed collections

a. By catch mortality: Marine seed collection in India discards 40-60% of caught fish juvenile impact pelagic ecosystem.
b. Transport stress: Overpacking polythene bags or delayed journey increases CO2/NH3 accumulation causing mortality.

Case studies from different regions

1. Tapi district, Gujarat India: The SC community in Tapi district employed a unique traditional method for fish seed collection .It involves using a steel dish covered with white cotton cloth with a 2-3cm hole at center. When flour is used as attractant drawing fish seed into the dish through the hole.

a. Operation: Device is placed in stagnant or slow flowing water typically at a depth of 3-5 feet for 1-2 hours. Fish seed mainly Indian major carps are attracted & collected without any damage.

b. Advantage : Cost effective cause no physical damage to fish & environmentally being and net suitable for running waters.

2. Calicut area ,Kerala ,India:

a. Drag net & tidal pool seed collections: Areas such as kardalundi , beypore and west hills are prominent for fish seed collection especially in tidal pools & estuarine environment.

b. Methods: Fish seeds are collected by using drag net in shallow pools & tidal areas during low tide. Nets are dragged along bottom seeds are carefully transferred to troughs with sample water for transport.

Species: Seeds of Milk fish & Mullets are continuously collected with peak abundance in June-July months.

Environment mounter: Parameters like temperature, salinity ,dissolved oxygen & Ph are regularly recorded to ensure optimal collection conditions**.**

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PRECISION FARMING

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Introduction

Timely and accurate information is essential in all phases of production from planning through post-harvest. Information available to the farmer includes crop characteristics, soil properties, fertility requirements, weed populations, insect populations, plant growth response, harvest data, and post-harvest processing data. Technology is rapidly evolving and the farmer must keep up with the changes that may be of benefit in his or her operation Sensors are available or under development that can monitor soil properties, crop condition, harvesting, or post-harvest processing and give instant results or feedback which can be used to adjust or control the operation. Without proper management, precision crop production would not be effective. Farmers must know how to interpret the information available, how to utilize the technology, and how to make sound production decisions

Definition

Precision farming has been the buzzword of agricultural research around the globe in recent times. It is based on the philosophy of heterogeneity within homogeneity and requires precise information on the degree of variability for within field management. The aim is to vary the agricultural inputs in response to the varying conditions within the field. This is just what *precision farming* is about - the use of mechanical and electronic aids to aim for the best crops, best gross margins and highest profitability our farm is capable of.

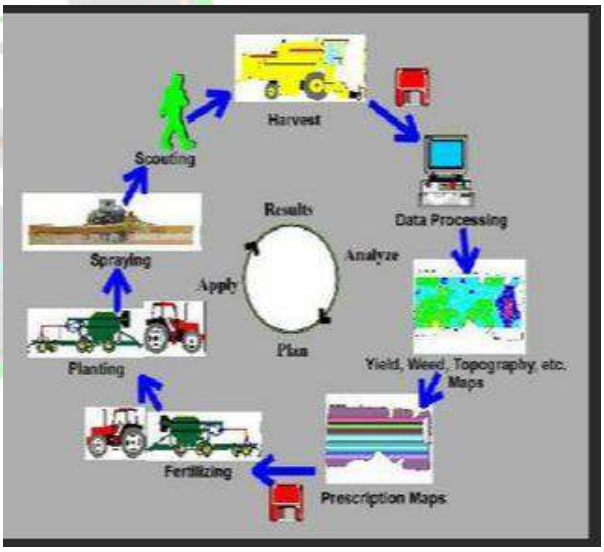
What is Precision Farming

The electronics revolution of the last several decades has spawned two technologies that will impact agriculture in the next decade. These technologies are Geographic Information Systems (GIS) and Global Positioning System (GPS). Along with GIS and GPS there have appeared a wide range of sensors, monitors and controllers for agricultural equipment such as shaft monitors, pressure transducers and servo motors. Together they will enable farmers to use electronic guidance aids to direct equipment movements more accurately, provide precise positioning for all equipment actions and chemical applications and, analyze all of that data in association with other sources of data (agronomic, climatic, etc). This will add up to a new and powerful toolbox of management tools for the progressive farm manager. Precision farming should not be thought of as only yield mapping and variable rate fertilizer application and evaluated on only one or the other. Precision farming technologies will affect the entire production function (and by extension, the management function) of the farm.

Objectives

Comprehensive precision agriculture has five major objectives:

- Increased production efficiency
- Improved product quality
- More efficient chemical use.
- Energy conservation.
- Soil and ground water protection



Components of Precision farming

1. Remote Sensing
2. GIS
3. DGPS
4. Variable rate Applicator

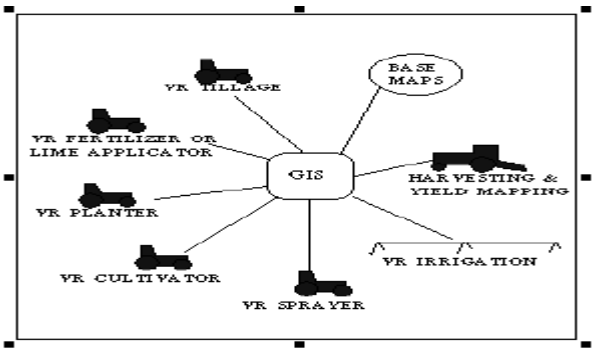


Fig. Precision Farming System

5. Overview

Applications of Precision farming

i) Yield monitoring. They provide a crop yield by time or distance (e.g. every second or every few metres).

ii) Yield mapping. GPS receivers coupled with yield monitors provide spatial coordinates for the yield monitor data. This can be made into yield maps of each field.

iii) Variable rate fertilizer. Variable rate controllers are available for granular, liquid and gaseous fertilizer materials.

iv) Weed mapping. A farmer can map weeds while combining, seeding, spraying or field scouting by using a keypad or buttons hooked up to a GPS receiver and datalogger.

v) Variable spraying. By knowing weed locations from weed mapping spot control can be implemented. Controllers are available to electronically turn booms on and off, and alter the amount (and blend) of herbicide applied.

vi) Topography and boundaries. Using high precision DGPS a very accurate topographic map can be made of any field. Field boundaries, roads, yards, tree stands and wetlands can all be accurately mapped to aid in farm planning.

vii) Salinity mapping. GPS can be coupled to a salinity meter sled which is towed behind an ATV (or pickup) across fields affected by salinity. Salinity mapping is valuable in interpreting yield maps and weed maps as well as tracking the change in salinity over time.

viii) Guidance systems. Guidance systems using high precision DGPS that can accurately points out the position of a moving vehicle within a foot or less.

ix) Records and analyses. Electronic sensors can collect a lot of data in a short period of time Electronic controllers can also be designed to provide signals that are recorded electronically. This means a large database is needed with the capability to archive, and retrieve,dataforfuture analyses.

Drawbacks in Precision farming

- High cost
- Lack of technical knowledge and technology
- Heterogeneity of cropping systems and market imperfections
- Costly for small land holding.

Conclusion

Precision farming is one of the most scientific and modern approaches to sustainable agriculture that has gained momentum in 21st century. Precision farming is essential for serving dual purpose of enhancing productivity and reducing ecological degradation. technologies without compromising the quality of land and thereby turning the green revolution into an evergreen revolution.

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SHUTTLE BREEDING: A POWERFUL TOOL FOR WIDE ADAPTATION IN AGRICULTURE

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Introduction

In the realm of agriculture, the quest for crops that can withstand diverse environmental conditions is perpetual. As climate change and varying soil types pose challenges to traditional farming methods, scientists and farmers alike are exploring innovative approaches to ensure food security. One such method gaining prominence is shuttle breeding, a technique that harnesses the strengths of multiple environments to develop crops with broader adaptability.

Understanding Shuttle Breeding

Shuttle breeding involves shuttling plant populations between two or more contrasting environments, typically from a stressed environment to a non-stressed or less stressed one. The primary objective is to expose the plants to a range of conditions, promoting the selection of traits that enhance adaptability. This cyclic process is repeated over several generations, leading to the development of crops with increased resilience to various stressors.

Advantages of Shuttle Breeding

Enhanced Adaptability: The fundamental advantage of shuttle breeding lies in its ability to create crops that can thrive in a spectrum of conditions. By subjecting plants to different environments, the breeding process encourages the selection of traits that are universally beneficial, resulting in crops with heightened adaptability.

Accelerated Breeding Programs: Shuttle breeding can significantly shorten the time required for traditional breeding programs. The rapid cycling of plant populations between environments allows for the observation and selection of desirable traits in a shorter time frame, expediting the breeding process.

Diversity in Genetic Pool: By exposing plants to diverse environmental conditions, shuttle breeding increases the genetic diversity within a crop. This diversity is crucial for building resilience against evolving pests, diseases, and changing climatic patterns, ultimately contributing to sustainable agriculture.

Optimized Resource Utilization: Shuttle breeding allows for the efficient utilization of resources. By selecting plants that perform well in specific environments, farmers can optimize their crop management strategies, leading to increased yields and reduced resource wastage.

Applications of Shuttle Breeding

Drought Tolerance: In regions prone to water scarcity, shuttle breeding has been instrumental in developing crops with improved drought tolerance. By shuttling plants between drought-stressed and well-watered environments, breeders can select for traits that enable plants to thrive in arid conditions.

Salinity Resistance: Coastal areas often face challenges related to soil salinity. Shuttle breeding programs targeting salinity resistance involve transferring plant populations between saline and non-saline environments, resulting in crops that can withstand high salt concentrations in the soil.

Key Features of Shuttle Breeding:

1. **Geographic Diversity**: By breeding in two distinct environments, breeders can take advantage of different growing conditions, such as temperature, rainfall, and soil types, which can influence plant traits.
2. **Selection Pressure**: Different environments impose various selection pressures on the crops, allowing for the identification of traits that confer resilience to stressors like drought, disease, and pests.
3. **Time Efficiency**: Shuttle breeding can accelerate the breeding cycle. By growing crops in multiple locations in different seasons (for example, one location in the dry season and another in the wet season), breeders can evaluate and select plants more quickly.
4. **Genetic Gain**: This method can lead to significant genetic gains by allowing for the selection of superior genotypes that perform well across multiple environments.

Applications

- **Cereal Crops**: Commonly used in the breeding of cereals like wheat and rice, where different locations can provide insights into how varieties perform under varying conditions.
- **Stress Tolerance**: Particularly valuable for developing varieties that can withstand abiotic stresses such as drought or salinity.

Example

In shuttle breeding for wheat, a breeder might grow a specific wheat variety in a drought-prone region during the dry season and then move the same variety to a more humid area during the wet season. This allows for the selection of plants that show desirable traits in both environments, ultimately leading to the development of a more resilient crop variety.

Overall, shuttle breeding is an effective strategy in plant breeding that leverages environmental variability to enhance crop performance and adaptability.

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CASHEW SPROUTS: NUTRITIONAL COMPOSITION AND HEALTH BENEFITS

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Introduction

In the dynamic field of nutrition and wellness, cashew sprouts have emerged as a noteworthy superfood, garnering the attention of both health enthusiasts and nutrition experts. Although cashews have long been recognized as nutritious snacks, the process of sprouting transforms these kidney-shaped nuts into nutritional powerhouses with enhanced bioavailability and digestive benefits. Sprouting is an ancient technique that involves soaking raw cashews in water to initiate natural germination (Oyewole and Koffa, 2010). This simple, yet transformative process activates dormant enzymes, reduces antinutrients, and significantly enhances the nutritional profile of these already impressive nuts. As research continues to reveal the extraordinary benefits of sprouted foods, cashew sprouts have proven to be one of the most efficient means of maximizing nutrition while maintaining optimal health (Menon *et al.*, 2022).

Cashew Sprouts and its germination.

Cashew sprouts are raw cashew nuts soaked in water for 2-4 hours to activate their natural sprouting mechanisms. This process does not involve visible sprouting, as seen in bean sprouts, but rather activates the enzymes of the nut and initiates biochemical changes that would naturally occur when cashews germinate in their native environment. The sprouting process triggers remarkable biochemical transformations in the cashew (Preethi *et al.*, 2022). According to researchers, sprouting foods results in increased activities of hydrolytic enzymes, improvement in the contents of certain essential amino acids, total sugars, and B-group vitamins, and a decrease in dry matter, starch, and antinutrients. During sprouting, natural enzyme

inhibitors of cashew are neutralized, enhancing the bioavailability of nutrients for human absorption. The soaking process releases enzyme inhibitors, facilitating better nutrient absorption and the breakdown of phytic acid, which binds to minerals to prevent absorption (Oyewole and Koffa, 2010).

Nutritional Composition of Cashew Sprouts

Cashew sprouts enhance macronutrient profile, and various studies have indicated that cashew sprouts exhibit a superior nutritional composition compared to their unsprouted counterparts. Cashew sprouts contained 2.48% total sugars, 4.70 g/100 g of protein, 17.18% fat, and 3.6 g/100 g of free amino acids (Preethi *et al.*, 2022; Semporé *et al.*, 2024).

Protein Enhancement

Sprouts are richer in proteins, with certain amino acids increasing by up to 30% compared to their non-sprouted counterparts, making cashew sprouts an excellent plant-based protein source for both vegetarians and vegans. Improved Fiber Content: When seeds sprout, fiber, particularly insoluble fiber, which nourishes beneficial gut bacteria and aids in preventing constipation, increases and becomes more bioavailable (Menon *et al.*, 2022).

Mineral Content

Cashew sprouts contains 22.22 mg/100 g of iron and 64.2 mg/100 g of calcium. Research indicates that cashew accessions are rich in minerals and essential amino acids and sprouting enhances the bioavailability of these crucial nutrients (Menon *et al.*, 2022). Cashews are a good source of nutrients, providing essential minerals that support various bodily functions. The sprouting process makes these minerals more readily available for absorption. During sprouting, antioxidants activate enzymes that increase the production of antioxidants such as vitamin C, vitamin E, and phenolic compounds, which help neutralize free radicals and protect against cellular damage. Cashew sprouts contain 420 mg/100 g phenol and 2.8 mg/100 g tannin, contributing to their potent antioxidant properties (Semporé *et al.*, 2024).

Health Benefits of Cashew Sprouts

1. Enhanced Digestive Health

A primary benefit of cashew sprouts is their improved digestibility. Sprouted nuts and seeds are more easily digested than their raw counterparts because of the soaking process, which releases enzyme inhibitors. The reduction in antinutrients during sprouting renders cashew sprouts particularly advantageous for individuals with sensitive digestive systems (Cordeiro,

2014). The sprouting process facilitates the breakdown of phytic acid, enhances the nutrient profile of foods, and neutralizes enzyme inhibitors while decomposing lectins, which are another category of anti-nutrients (Miyahira *et al.*, 2021).

2. Superior Nutrient Absorption

Research suggests that sprouting certain grains and legumes can enhance their antioxidants, amino acids, and B vitamins while reducing antinutrients such as phytic acid, which can impede the absorption of other essential vitamins and minerals. This increased bioavailability allows the body to extract and utilize more nutrients from cashew sprouts than from regular cashews, making them a more efficient nutritional source (Vyavahare *et al.*, 2020).

3. Antioxidant Protection

Antioxidant Protection Sprouts are rich in phytonutrients, such as glycosylates, phenolics, and isoflavones, and numerous studies have demonstrated that sprouts contain high concentrations of vitamins and minerals. Antioxidant compounds in cashew sprouts help protect cells from oxidative stress and may contribute to reducing the risk of chronic diseases associated with free radical damage (Vyavahare *et al.*, 2020).

4. Immune System Support

The enhanced vitamin and mineral content, particularly the increased bioavailability of essential nutrients like zinc, vitamin E, and phenolic compounds, supports optimal immune function (Miyahira *et al.*, 2021).

Practical Applications and Uses

1. Culinary Versatility

Cashew sprouts offer remarkable versatility in the kitchen. They can be consumed raw as a nutritious snack, added to salads for extra crunch and nutrition, or incorporated into smoothies for added protein and healthy fats (Malhotra *et al.*, 2017).

2. Storage and Preparation

For optimal freshness and safety, cashew sprouts should be stored in airtight containers in the refrigerator and consumed within 1-2 weeks. The sprouting process can be easily done at home by soaking raw cashews in filtered water for 2-4 hours, then draining and air-drying (Malhotra *et al.*, 2017).

Conclusion

Cashew sprouts represent a significant advancement in optimizing the nutrition of whole foods. Through the simple process of sprouting, these nutritious nuts become more digestible, nutrient dense, and bioavailable. This study clearly demonstrates that sprouting enhances protein content, increases antioxidant levels, improves mineral absorption, and supports overall digestive health. As health and wellness communities continue to seek natural ways to maximize nutrition, cashew sprouts offer an accessible, affordable, and scientifically supported option. Whether consumed as a standalone snack or incorporated into various culinary applications, cashew sprouts provide an excellent means of enhancing dietary nutrition while maintaining optimal health. For individuals seeking to upgrade their nutrition naturally, cashew sprouts offer a simple yet powerful solution that combines ancient wisdom with modern nutritional science. As research continues to unveil the benefits of sprouted foods, cashew sprouts have become an essential component of health-conscious diets.

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PERSISTENT POLLUTANTS: THE AQUATIC THREAT OF PAHS

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Abstract

Polycyclic Aromatic Hydrocarbons (PAHs) are persistent, toxic organic compounds made of fused benzene rings, formed mainly by incomplete combustion and present in fuels, industrial products, and crude oil. They enter aquatic systems through spills, runoff, and emissions. PAHs cause acute and chronic toxicity in fish, invertebrates, and algae, leading to developmental deformities, liver damage, immune suppression, and altered behavior. They accumulate in sediments and organisms like mussels, impacting food webs and human health. Petrogenic, pyrogenic, and biological sources contribute to PAH pollution. Contaminated seafood and water pose risks of cancer and organ damage, highlighting the need for monitoring and regulation.

Keywords – PAH, Persistent, Toxic,

Introduction

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds that are mostly colorless, white, or pale yellow solids. They are a ubiquitous group of several hundred chemically related compounds, environmentally persistent with various structures and varied toxicity. s. Chemically the PAHs are comprised of two or more benzene rings bonded in linear, cluster, or angular arrangements. Although there are many PAHs, most regulations, analyses, and data reporting focus on only a limited number of PAHs, typically between 14 and 20 individual PAH compounds. The general characteristics of PAHs are high melting and boiling points (therefore they are solid), low vapor pressure, and very low aqueous solubility. The major source of PAHs is the incomplete combustion of organic material such as coal, oil and wood. They are

mostly used as intermediaries in pharmaceuticals, agricultural products, photographic products, thermosetting plastics, lubricating materials, and other chemical industries. However, the general uses of some PAHs are:

- Acenaphthene: manufacture of pigments, dyes, plastics, pesticides and pharmaceuticals.
- Anthracene: diluent for wood preservatives and manufacture of dyes and pigments
- Fluoranthene: manufacture of agrochemicals, dyes and pharmaceuticals.
- Fluorene: manufacture of pharmaceuticals, pigments, dyes, pesticides and thermoset plastic. Phenanthrene: manufacture of resins and pesticides.
- Pyrene: manufacture of pigments.

Sources of PAH

The following three types: pyrogenic, petrogenic, and biological are the major PAH sources to the environment. PAHs are primarily formed through pyrolysis, where organic materials are exposed to high temperatures (350–1200 °C) under low or no oxygen. This includes intentional processes like coal coking and petroleum cracking, and unintentional ones like incomplete combustion in vehicles, forest fires, or heating systems. These pyrogenic PAHs are common in urban and industrial areas. Petrogenic PAHs, on the other hand, form naturally over millions of years at lower temperatures (100–150 °C) during crude oil formation. They are prevalent in petroleum products and released through oil spills, fuel leaks, and other transportation-related sources. PAHs can also originate biologically, produced by certain plants, microbes, or during natural vegetation decay.

Examples of anthropogenic sources of PAHs range from:

- Large point sources include incomplete combustion (such as incinerators and some industrial processes.
- Smaller point sources include, dispersed sources (such as automotive emissions, smoke from wood-burning stoves, jet aircraft exhausts, cigarette and cigar smoke, and backyard barbecues).
- Other anthropogenic sources of PAHs include petroleum product spills, sewage sludge, and tarry or creosote waste materials.

Impact of PAH in aquatic ecosystem

- ✓ **Toxicity to Aquatic Life**

PAHs can cause **both acute and chronic toxicity** in aquatic organisms. They interfere with cellular processes, damage DNA, and induce oxidative stress.

- **Acute toxicity**: Short-term exposure to high levels of PAHs (e.g., after an oil spill) can lead to fish kills, gill damage, and reduced oxygen uptake.
- **Chronic toxicity**: Long-term exposure to even low concentrations may lead to sublethal effects such as reduced growth, abnormal development, and endocrine disruption.

Eg - After the *Exxon Valdez oil spill* in Alaska (1989), pink salmon embryos exposed to PAHs in sediments showed high mortality and deformities.

✓ **Bioaccumulation and Biomagnification**

PAHs, being **hydrophobic**, tend to accumulate in the fatty tissues of aquatic organisms. Bottom-dwelling and filter-feeding species accumulate PAHs through contact with contaminated sediments or by ingesting tainted food. While PAHs may not biomagnify as strongly as some other pollutants, **persistent exposure** along the food chain can result in significant contamination of higher organisms, including humans.

Eg - Mussels (e.g., *Mytilus edulis*) in polluted harbors often accumulate high levels of PAHs and are used as **bioindicators** in marine pollution monitoring (e.g., "Mussel Watch" programs).

✓ **Impact on Fish**

Fish are highly sensitive to PAHs, especially during their **early life stages**.

- **Developmental effects**: Embryos exposed to PAHs may show spinal deformities, pericardial edema (fluid around the heart), or yolk sac abnormalities.
- **Liver damage**: PAHs are metabolized in the liver, which may lead to **enzyme induction**, tissue damage, or tumors.
- **Immune suppression**: Reduced resistance to pathogens, leading to secondary infections.
- **Behavioral changes**: Reduced predator avoidance, disrupted schooling, and impaired foraging.

Eg - Atlantic killifish (*Fundulus heteroclitus*) from polluted sites like the Elizabeth River (USA) exhibit resistance to PAH toxicity but show liver abnormalities due to constant exposure.

✓ **Impact on Invertebrates**

Benthic invertebrates, such as **polychaetes, amphipods, and mollusks**, are especially at risk due to their constant contact with contaminated sediments.

- PAHs can reduce survival, inhibit growth, delay reproduction, and alter burrowing and feeding behavior.
- Some species may disappear entirely from highly polluted environments.

Example: In sediment toxicity tests, amphipods (*Ampelisca abdita*) show high mortality when exposed to PAH-contaminated sediments, making them valuable in ecotoxicological assessments.

✓ **Sediment Contamination**

PAHs settle in sediments due to their low solubility in water and high affinity for organic matter. These contaminated sediments can act as a **long-term source of PAHs**, leaching them slowly back into the water. Sediment disturbance from dredging or storms can **resuspend PAHs**, exposing aquatic life again.

Example: Sediments from the Hudson River (USA), contaminated by industrial discharge, contain elevated levels of PAHs, impacting benthic organisms and requiring costly remediation.

✓ **Human Health Risks via Aquatic Exposure**

Humans may be exposed to PAHs through **eating contaminated seafood**, direct contact with polluted water, or inhalation of volatile compounds. **Carcinogenic PAHs** like benzo[a]pyrene pose a significant health concern. Long-term dietary exposure may increase risks of liver damage, reproductive effects, or cancers.

Example: Fish and shellfish from areas affected by oil spills (e.g., *Deepwater Horizon* in the Gulf of Mexico) were subject to strict monitoring before they were declared safe for consumption.

Conclusion

PAHs are dangerous to aquatic ecosystems due to their **chemical stability**, **toxicity**, and **widespread sources**. Their presence affects organisms at all trophic levels and can lead to long-lasting ecological damage and potential risks to human health. Regular monitoring, pollution control, and cleanup of contaminated sediments are essential to protect aquatic life and ecosystem services.

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FEED ADDITIVES IN AQUACULTURE: ENHANCING NUTRITION, HEALTH, AND SUSTAINABILITY

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Abstract

The intensification of aquaculture has driven the development and application of feed additives to improve growth performance, feed utilization, immunity, and disease resistance in farmed aquatic animals. This review explores the various categories of feed additives used in aquaculture, including probiotics, prebiotics, enzymes, immunostimulants, phytogenics, and organic acids. Their mechanisms of action, benefits, and challenges in practical implementation are discussed. The paper also highlights the role of feed additives in reducing antibiotic use and environmental impact, making them integral to sustainable aquaculture practices.

Introduction

Aquaculture, the farming of aquatic organisms, has emerged as the fastest-growing food-producing sector globally. As demand for aquatic protein increases, intensive farming practices have become commonplace, often accompanied by issues related to disease outbreaks, poor feed conversion, and environmental degradation. To address these challenges, the use of functional feed additives has gained considerable attention. Feed additives are substances included in aquafeeds at low concentrations to improve growth, feed efficiency, health status, or environmental sustainability. While traditional aquafeeds focus primarily on meeting basic nutritional requirements, modern functional feeds incorporate additives to support physiological functions, enhance immunity, and reduce dependency on chemotherapeutics.

Categories of Feed Additives

- **Probiotics**

Probiotics are live microorganisms that, when administered in adequate amounts, confer health benefits to the host. In aquaculture, probiotics such as *Lactobacillus spp.*, *Bacillus spp.*,

and *Saccharomyces cerevisiae* have been used to improve gut microbiota, enhance digestion, and inhibit pathogenic bacteria. They can be delivered via feed or water.

Mechanisms of action include competitive exclusion of pathogens, production of antimicrobial substances, immune modulation, and improved nutrient assimilation. Studies have shown that probiotic supplementation can enhance weight gain, feed conversion ratio (FCR), and disease resistance in species like tilapia, shrimp, and carp.

- **Prebiotics**

Prebiotics are non-digestible food ingredients that selectively stimulate the growth or activity of beneficial gut bacteria. Common prebiotics used in aquaculture include inulin, fructooligosaccharides (FOS), galactooligosaccharides (GOS), and mannanoligosaccharides (MOS).

These compounds promote gut health by enhancing the proliferation of beneficial microbiota such as *Lactobacillus* and *Bifidobacterium*, which in turn suppress harmful bacteria and improve nutrient absorption. Prebiotics are often used in combination with probiotics (synbiotics) for synergistic effects.

- **Enzymes**

Exogenous enzymes, including phytase, protease, lipase, and carbohydrases, are added to feeds to enhance nutrient digestibility. This is particularly important in plant-based diets where anti-nutritional factors (ANFs) limit nutrient availability.

Phytase, for instance, breaks down phytic acid, a form of phosphorus in plant ingredients that is poorly digested by fish and shrimp. Enzyme supplementation improves feed efficiency, growth performance, and reduces environmental phosphorus loading.

- **Immunostimulants**

These are natural or synthetic substances that enhance the innate immune system of aquatic animals. Common immunostimulants include β-glucans, chitosan, levamisole, and nucleotides.

By activating macrophages, lysozymes, and other immune cells, these additives increase resistance to bacterial, viral, and parasitic infections. Immunostimulants are particularly valuable during critical periods such as vaccination, weaning, and environmental stress.

- **Phytogenics (Plant-Based Additives)**

Phytogenics include herbs, spices, essential oils, and plant extracts with bioactive properties.

Garlic (*Allium sativum*), turmeric (*Curcuma longa*), oregano oil, and neem (*Azadirachta indica*) are commonly used.

These additives exert antimicrobial, antioxidant, anti-inflammatory, and growth-promoting effects. Their natural origin and low risk of resistance development make them attractive alternatives to antibiotics.

- **Organic Acids**

Organic acids such as citric, formic, lactic, and butyric acids are used to modulate gut pH, inhibit pathogenic bacteria, and improve mineral absorption. They can also act as acidifiers to preserve feed quality.

Butyric acid, in particular, has gained attention for its role in enhancing gut morphology and epithelial integrity, thereby improving nutrient uptake and immune function.

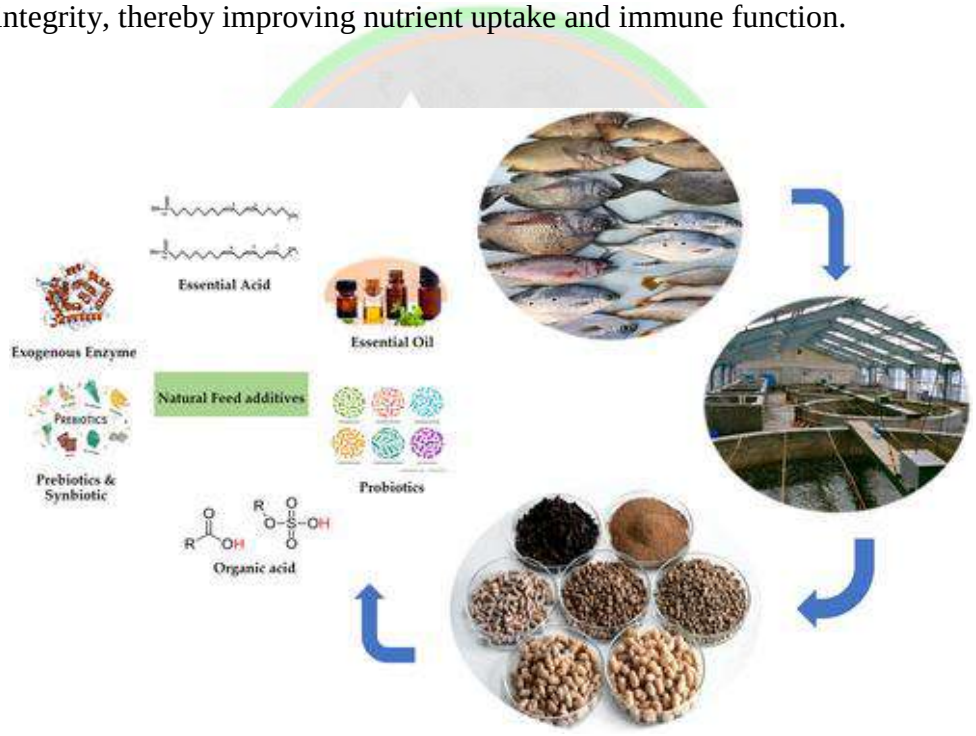


Figure 1:Natural feed additives

Benefits and Applications

The application of feed additives has demonstrated multiple benefits in aquaculture systems:

- **Growth Performance**: Improved weight gain, FCR, and protein efficiency ratio (PER).
- **Health and Immunity**: Increased disease resistance and stress tolerance.
- **Water Quality**: Reduced nutrient excretion and improved environmental footprint.

- **Antibiotic Reduction**: Lower dependence on antimicrobials through preventive health measures.

Additives are used in both freshwater and marine systems and across diverse species including finfish (e.g., salmon, tilapia, catfish) and shellfish (e.g., shrimp, crab).

Challenges and Considerations

Despite the benefits, the use of feed additives in aquaculture is not without limitations:

- **Species-Specific Responses**: Efficacy varies between species, life stages, and environmental conditions.
- **Standardization**: Lack of standardized dosages and quality control can affect consistency.
- **Cost**: Some additives increase feed cost, which may not always translate to proportional performance gains.
- **Regulatory Issues**: Varying global regulations impact the approval and labeling of functional feed ingredients.

Moreover, overuse or misuse of certain additives may lead to unintended ecological or health consequences, warranting careful formulation and scientific validation.

Future Perspectives

The future of feed additives in aquaculture lies in precision nutrition and tailored functional feeds. Advances in genomics, microbiome research, and nanotechnology will enable more targeted applications. Integration of novel ingredients like algae-derived compounds, peptides, and CRISPR-based probiotics may further enhance feed efficiency and disease resilience.

Sustainable sourcing and lifecycle assessments will become critical as the industry shifts towards circular and climate-smart aquaculture. Public and private sector collaboration is essential for research, innovation, and regulatory harmonization.

Conclusion

Feed additives represent a promising tool for enhancing aquaculture performance, animal welfare, and environmental sustainability. When selected and applied judiciously, they can reduce the industry's reliance on antibiotics, improve productivity, and support the transition to more resilient food systems. Continued research, innovation, and policy support are vital for maximizing their potential and ensuring safe, effective, and economically viable applications.

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MORPHOLOGY AND PHYSIOLOGY OF SILKWORM EGG

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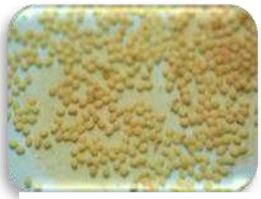
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Introduction

Silkworm is a lepidopteron insect which produces the valuable proteinaceous secretion called silk fiber in one phase of its lifecycle. Based on feeding habit, silkworms are of two types one is mulberry silkworm (*Bombyx mori*) and another one is vanya silkworm. Mulberry silkworm feed only on mulberry leaves in its entire larval stage (monophagous) whereas vanya silkworms feed on hosts other than mulberry and are mostly polyphagous in nature. An egg is the first stage in the life cycle of the silkworm. The egg is laid by a female moth and is mostly the size of small dots. Egg is the backbone of silk industry. This paper highlights the morphological structures and physiological changes in the silkworm egg.

Morphology of Mulberry silkworm (*Bombyx mori*) egg

Naturally, female silkworms lay eggs in clusters, typically on mulberry leaves and cover them with a gelatinous secretion which helps them to stick. Eggs laid by single moth are called one DFL (Disease Free Laying). A single moth lays approximately 300 to 500 eggs. Races producing white cocoons lay pale yellow eggs. Japanese races lay slightly darker eggs than the Chinese races. In case of hibernating eggs laid by bivoltine and univoltine races, the egg colour changes and becomes dark brown or purple with the deepening on the colour of the serosal pigments.



Freshly laid eggs



Eggs going to hatch

S.No	Physical properties	Characteristics
1.	Size	Silkworm eggs are tiny, measuring around 1-1.3 mm in length and 0.9-1.2 mm in width.
2.	Shape	Silkworm eggs are typically oval or ellipsoidal.
3.	Colour	Freshly laid eggs are often yellowish, but they can change to white or black depending on fertilization status. White eggs are typically infertile, while black eggs are fertile.
4.	Weight	Approximately 0.5 mg
5.	Incubation period	The silkworm eggs hatch after an incubation period of 10 days, which may vary depending upon the strain and environmental conditions.

Morphology of Tasar (*Antharaea mylitta*) silkworm egg



Tasar silkworm moths lay eggs in masses after the female moths mate and are usually kept in bamboo baskets for 48 hours. A single female tasar moth (*Antheraea mylitta*) lays approximately 150-200 eggs in a two-day period. The eggs are characterized by a bilateral symmetry along the antero-posterior axis and are divided into three zones by two brownish parallel lines along the equatorial plane.

S.No	Physical properties	Characteristics
1.	Size	Approximately 3mm in length and 2.5mm in diameter
2.	Shape	Oval, dorso-ventrally flattened
3.	Colour	White or light brown when laid. Two brownish parallel lines along the equatorial plane of the egg divide the surface into three zones (disk, streak, edge)
4.	Weight	Approximately 10 mg
5.	Incubation period	Hatching occurs within 9-10 days during summer and 15-20 days in winter.

Morphology of Eri (*Philosamia ricini*) silkworm egg



Eri silkworm eggs are typically laid in clusters on the lower surface of the host plant leaves. A female moth after copulation lays about 300-500 eggs in cluster. The laying may continue for 3 to 4 days but the eggs of first two days are only kept for rearing. The eggs are sticky and covered with a gummy substance, which helps them adhere to each other and with the leaf surface. Eggs are covered by a hard chitinious white coloured shell and at the time of hatching, egg shell cracks at one end and the larva wriggles out.

S.No	Physical properties	Characteristics
1.	**Size**	Around 1.5 x 1.0 mm
2.	**Shape**	Ovoid or flat, ellipsoidal, and oval
3.	**Colour**	Initially milky white, then creamy white, and finally becoming darker to violet just before hatching
4.	**Weight**	Approximately 6 mg
5.	**Incubation period**	Approximately 7-10 days

Morphology of Muga (*Antheraea assamensis*) silkworm egg



Wild muga moths have a fecundity of 220-227 eggs while cultivated muga moths have a fecundity of 120-170 eggs. They have a hard, chitinous shell composed of rounded cells and are covered with sticky brown glue that helps them to adhere on the surfaces. In wild muga, embryonic development takes 9-13 days under suitable conditions and can extend to 18-20 days in low temperatures. Cultivated muga eggs hatch 9-10 days after oviposition and development can extend upto 12-14 days in low temperatures. Eggs of cultivated muga have less distinct streaks compared to wild muga eggs.

S.No	Physical properties	Characteristics
1.	**Size**	Approximately 2.8 x 2.5 mm
2.	**Shape**	Oval
3.	**Colour**	Brownish coloured. Brown glue on the surface helps them adhere to surfaces
4.	**Weight**	Approximately 9 mg

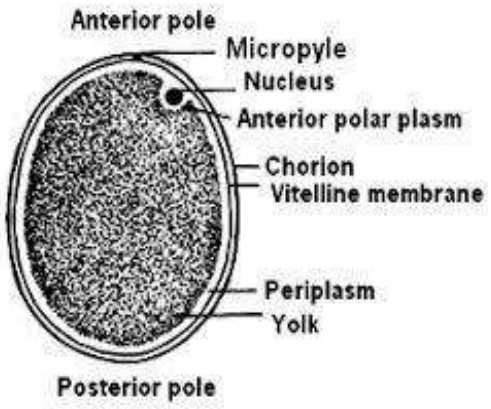
5.	**Incubation period**	Approximately 9-10 days

External structures of silkworm egg

S.No	Physical structures	Characteristics
1.	**Chorion**	The outer protective shell is called the chorion
2.	**Micropyle**	The chorion has an opening at the anterior end through which the sperm enters is called micropyle
3.	**Respiratory canals**	Small, funnel-shaped respiratory canals are distributed on the egg's surface which allows air to enter for respiration

Internal structures of silkworm egg

S.No	Physical structure	Characteristics
1.	**Vitelline Membrane**	A thin membrane inside the chorion that encloses the protoplasm and yolk
2.	**Protoplasm**	The cytoplasm and nucleus of the egg
3.	**Yolk**	A store of nutrients for the developing larva, located just below the vitelline membrane
4.	**Periplasm**	A thin layer of cytoplasm that does not contain yolk, particularly thick around the micropyle
5.	**Anterior Polarplasm**	The area around the micropyle that contains the egg's nucleus



Structure of silkworm egg

Physiological changes in silkworm egg

Silkworm eggs undergo significant physiological changes during their development from laying to hatching. These changes involve the mobilization of stored nutrients, development of embryonic tissues and the regulation of diapause (a dormant state) in some silkworm races.

1. Nutrient Mobilization

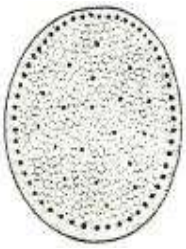
- Silkworm eggs contain yolk proteins (vitellin, egg-specific protein, and 30 kDa proteins) that serve as a primary source of nutrients for embryonic development.
- During embryogenesis, these proteins are mobilized and utilized as energy and building blocks for developing tissues.

2. Embryogenesis (Embryonic Development)

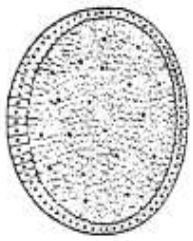
Embryonic development involves a series of cell divisions and differentiation processes that lead to the formation of the larva. Temperature, humidity, and other environmental factors can influence the rate and success of embryonic development. It is important to understand the embryonic development of silkworm eggs for proper preservation of the eggs.

1. Cleavage, blastoderm and germ band formation

After fertilization, cleavage proceeds through a succession of synchronous mitotic divisions of the zygote nucleus and its daughter nuclei migrate through the yolk mass. The mitotic spindles of each synchronous division are randomly oriented and a number of nuclei progressively approach the periplasm. The rate at which synchronous divisions proceed within the yolk mass is one mitotic cycle per hour (11 times synchronous mitosis). The cleavage nuclei migrate to the periplasm and surround the yolk mass which indicates the formation of the blastoderm. Few of nuclei remain within the yolk masses. Blastoderm formation occurs about 12 hours after oviposition. At about 15 hours after oviposition, the cell inside the presumptive embryonic primordium area increases in thickness and becomes concentrated and still increasing in number through cell division.



Blastoderm formation



Germband formation

This area in the blastoderm extends broadly on the ventral to ventro-lateral side of the egg and is called the germ band.

2. Growth of the embryo

The germ band grows by cell division and differentiates into three germinal layers which are ectoderm, mesoderm and endoderm. It is followed by surface partitioning whereby the body segmentation and appendages are set out.

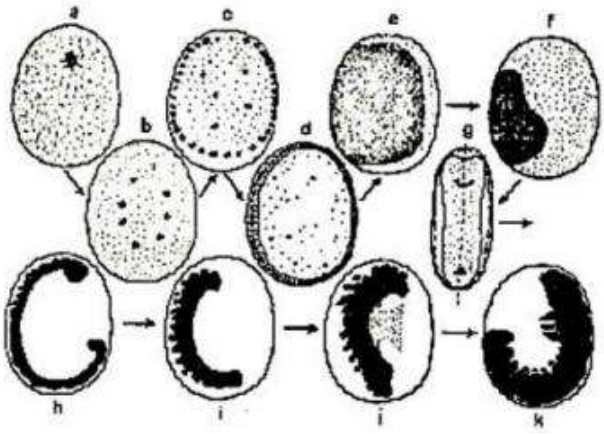
3. Blastokinesis

The silkworm embryo, like other species of Lepidoptera undergoes marked changes in position and orientation within the egg space as development proceeds. This embryonic movement is referred to as blastokinesis. After about 10 days from the time of oviposition, formation of embryo gets completed (figure A,B,C).



A **B** **C**

Diagrammatic representation of embryonic development in the silkworm egg



a - fertilization, 2 h after oviposition; **b** - early cleavage, 8 h after oviposition; **c:** late cleavage ; **d** - formation of blastoderm ; **e** - formation of germ band, 15h after oviposition.; **f** - germ band, 24h after oviposition; **g** - gastrulation ; **h** - formation of stomodeum and proctodeum, 2 days after oviposition; **I** : formation of appendages, 3 days after oviposition; **j** - blastokinesis, 4days after oviposition; **k** - completion of embryo, 8-10days after oviposition

- **Ectoderm**

  Ectoderm develops into epidermis and its appendages, ocellus, salivary gland, prothoracic gland, corpora allta, molting gland, oenocyte, silk gland, fore-gut and hind-gut, Malpighian tube, trachea, nervous organ, and outer reproductive organ.

- **Mesoderm**

  Mesoderm develops into inner part of reproductive organ, muscles, dorsal vessel, sub-oesophagial ganglion, fat body, blood cells and pericardial glands.

- **Endoderm**

  From endoderm mid-gut is formed

The Timetable of embryogenesis of the silkworm at 25℃

Time period from laying	Physiological Changes
0-2 h	The second maturation division and syngamy occur
2-10 h	Progress of synchronous cleavage mitosis followed by uniform invasion of periplasm.
12 h	The syncytial blastoderm is established
20 h	The germ band is formed (Suitable for acid treatment in case of artificial hatching)
25 h	Gastrulation accompanied by elongation of the germ band
35 h	Segmentation of the mesoderm gets completed and 17 segments can be clearly observed
40 h	The appendages at the head and thoracic region develops. At this stage, the egg enters diapause (dormant period) in univoltine races
48 h	Differentiation of the appendages at the abdominal region
2.5 days	Invagination of the proctodeum takes place and reaches between 18th and 19th segment
3 days	Invagination of the trachea is initiated
3.5 days	Invagination of the proctodeum proceeds and reaches the 16th segment
4 days	Blastokinesis has begun

5 days	Blastokinesis is completed
6 days	External processes formed
7 days	Taenidium in spiral band is formed in the tracheal tube
8 days	Pigmentation begins at the head
9 days	Pigments formed at seta and epithelium
9.5 days	Hatching

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BANANA'S BLACK SPOT ENEMY: UNDERSTANDING AND MANAGING ANTHRACNOSE DISEASE

Article ID: AG-V05-I07-26

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Abstract

Anthracnose, caused by the fungal pathogen *Colletotrichum musae*, is a significant post-harvest disease affecting banana production worldwide. Characterized by dark lesions, fruit rot, and reduced marketability, anthracnose poses a serious threat to both smallholder farmers and commercial exporters. This article provides a comprehensive overview of the disease, including its etymology, historical context, symptoms, epidemiology, and integrated management strategies. Emphasis is placed on sustainable practices such as biological control, post-harvest treatments, and improved field hygiene. Understanding anthracnose and implementing effective control measures is essential to ensure fruit quality, reduce economic losses, and support the long-term sustainability of banana cultivation.

Introduction

Bananas are a staple fruit crop in many tropical and subtropical regions, valued for their nutritional content and economic importance. However, their production is increasingly threatened by anthracnose, a fungal disease that causes black spots, decay, and significant post-harvest losses. The disease is particularly problematic in humid climates and during storage and transport, where latent infections become symptomatic. This article explores the biology, spread, and management of anthracnose in bananas, with a focus on practical and sustainable solutions.

Etiology and Pathogen Biology

Anthracnose in bananas is primarily caused by *Colletotrichum musae*, a fungal pathogen that infects fruit, leaves, and stems. The disease is highly infectious and spreads through:

- Contaminated water (rain splash or irrigation)
- Infected planting material (suckers or tissue culture)
- Soil-borne inoculum

The pathogen thrives in warm (25–30°C), humid environments and can remain dormant on green bananas, becoming active during ripening.

Historical Context

The term "anthracnose" derives from the Greek words *anthrax* (coal) and *nosos* (disease), referring to the dark, sunken lesions it produces. Though recognized for centuries, the causal agent in bananas was identified in the 19th century with the advent of plant pathology. During the 20th-century banana export boom, anthracnose became a major concern due to its impact on fruit quality during transit. Despite advances in fungicides and storage, the disease remains a persistent challenge, exacerbated by climate change and reduced reliance on chemical controls.

Symptoms

Anthracnose manifests in several ways:

- **Fruit lesions**: Dark, sunken spots that may coalesce and lead to rot.
- **Leaf spots**: Small, dark lesions that can cause defoliation.
- **Stem lesions**: Damage to vascular tissues, reducing plant vigor and yield.
- **Post-harvest rot**: Infected fruit may decay during storage or transport.

Favorable Conditions for Disease Development

- High humidity and rainfall
- Warm temperatures (25–30°C)
- Dense plantings with poor air circulation
- Mechanical injuries to fruit
- Inadequate post-harvest sanitation

Integrated Disease Management

Field-Level Practices

- Prune and destroy infected plant debris.
- Maintain optimal spacing to improve airflow.

- Use resistant or tolerant cultivars where available.

Harvest and Handling

- Harvest during dry conditions to minimize spore spread.
- Handle fruit gently to avoid skin injuries.
- Wash fruit in clean or fungicide-treated water.

Post-Harvest Treatments

- **Hot water treatment**: Immersion at 50°C for 5 minutes reduces fungal load.
- **Fungicidal dips**: Application of thiabendazole or prochloraz.
- **Cold storage**: Slows fungal growth and extends shelf life.

Biological Control

- Use of antagonistic organisms such as *Trichoderma spp.* and *Bacillus subtilis* has shown promise in suppressing *Colletotrichum* on fruit surfaces.

Economic and Agricultural Significance

Anthracnose can cause up to 30–40% post-harvest losses in banana-producing regions. Even minor blemishes can lead to rejection in export markets, directly impacting farmer income and food security. Effective management is therefore critical not only for maintaining fruit quality but also for sustaining livelihoods.

Conclusion

Anthracnose remains a formidable challenge in banana cultivation, particularly in regions with conducive environmental conditions. A holistic approach—combining cultural practices, post-harvest treatments, and biological control—is essential for effective disease management. Continued research and farmer education are vital to developing sustainable solutions that safeguard banana production and ensure market competitiveness.

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MITIGATING HEAT STRESS IN PIGS: STRATEGIES FOR A RESILIENT PORK INDUSTRY

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Introduction

Heat stress is becoming a more significant issue in the pork industry, especially in tropical countries of the world like India. The pigs mostly rely on breathing and behavioural reactions to control their body temperature because they lack functional sweat glands. Long-term exposure to high ambient temperatures have detrimental effects on pigs' productivity, reproduction, and general health, which can lead to significant financial losses. It is essential to implement comprehensive mitigating measures. This paper explores practical and science-based approaches to mitigate the consequences of heat stress on pig production.

Challenges associated with thermal stress.

Heat stress	Pigs do not sweat efficiently, which leads to overheating, which can lead to panting (rapid shallow breathing), lethargy or lying flat on their sides, open-mouth breathing, reduced movement or interest in feed, and increased water intake.

Decreased feed intake	High temperatures significantly suppress appetite in pigs, and this effect can result in poor weight gain in piglets, reduced milk production in lactating sows, and slower growth rates in growing and fattening pigs.
Poor Reproductive Performance	**It would affect boars as well as sows differently:** **Boars:** reduced the sperm quality and decreased libido (can last several weeks). **Sows:** irregular estrus, lower conception rates, higher embryonic loss. **Lactating sows:** lower milk yield and feed intake, leading to poor piglet growth or higher mortality.
Dehydration	Increased water loss through respiration and urination, which shows sunken eyes, dry mouth and nose, and reduced skin elasticity, leads to weight loss and a weakened immune system.
Fly and Parasite incidence	Warm and moist conditions favour the breeding of flies and internal/external parasites. The parasite load on pigs, particularly flies, lice, and worms, causes skin irritation, weakness, disease transmission (e.g., swine dysentery), and additional stress like diarrhoea and sunburn, especially in young pigs.
Digestive Disorders	High temperatures can lead to diarrhoea (due to water imbalance or spoiled feed) and gut health issues (reduced feed intake), which lead to immune suppression.
Behavioral Changes	In pigs that are under heat stress, behavioural changes occur. Pigs may become more aggressive or lethargic, reduce play or interaction, and group around waterers or wet areas.

Challenges associated with heat stress in the different categories of pigs

Boar	**Heat stress has a direct effect on male fertility: it affects the testicles, leads to a lower sperm count, poor sperm motility, and increased abnormal sperm.** If a sow experiences fertility issues due to summer heat, these problems may continue for 6 to 8 weeks after the heat event. **Decreased Libido (Sex Drive):** Boars become lethargic and less interested in mating. **Testicular Damage:** Long-term exposure to high temperatures can cause permanent damage to the testes and result in chronic fertility issues or even

	infertility. **Poor breeding performance:** Lower conception rates in sows bred with heat-stressed boars and smaller litter sizes.
Lactating sow and Piglets:	Newborn piglets have poor temperature regulation capability. High ambient temperatures can cause hyperthermia (overheating), which leads to lethargy, dehydration, and increased mortality. Piglets may get reduced colostrum intake and inadequate passive immunity. Due to the combined effects of low birth weight, reduced colostrum intake, and overheating. The piglets are experiencing reduced Average Daily Gain (ADG) and lighter weaning weights during the summer. **Diarrhea and Infections:** The growth of bacteria like E. coli is favored in this environment. If the shed's hygiene is poor, it can lead to diarrhea and gut infections. Competition during suckling: Smaller/weaker piglets become more stressed and can't compete with littermates, and there is greater variability within the litter performance. **Management** Colostrum Feeding: It assists the weaker piglets with suckling and separating, enabling them to adopt supplemental colostrum for rearing affected piglets. Introduce creep feed to the piglets as soon as possible after farrowing to enhance their growth.
Pregnant pigs (sows)	In this season, the pregnant sow reduces feed intake and lowers her appetite, leading to poor body condition and lower energy reserves before farrowing. Reproductive Performance: The sow conception rate is reduced with irregular or delayed estrus and losses of embryos in early gestation. The sow farrowing in the summer has a smaller litter size and lower birth weight of piglets. Fetal Development: The pregnant sow may reduce uterine blood flow, affecting oxygen and nutrient supply to the fetuses. It may cause intrauterine growth restriction (IUGR). The number of stillborn piglets is higher; piglets' mortality before weaning is

	more likely due to low vitality and inadequate colostrum/milk intake.
Dry Sows	Estrus Detection: Check for heat signs regularly and use boar exposure for the detection of estrus. The tools to be used for the detection of heat like vaginal impedance meters or heat detectors.
Grower and finisher pigs	Grower and finisher pigs have 10 to 30% less feed intake in summer, to reduce internal heat production, resulting in a slower growth rate (↓ ADG) and poor feed conversion ratio (↑ FCR). These pigs with less energy intake take a longer time to reach market weight, which increases their feed costs and rearing costs. The pig raised in the summer season tends to deposit more fat instead of lean muscle and has a lower dressing percentage. Transport: Transporting pigs during peak heat hours increases the risk of heat stroke and death.



Sprinkling pigs with water during the summer

Practices to minimize the exposure of pigs to heat stress:

- Pigs are highly sensitive to heat because they lack functional sweat glands and rely on panting and behavioral changes to cool down the body temperature.

- **Temperature thresholds for different categories of pigs**

Sr. No.	**Pig Category**	**Upper critical temp (°C)**
1.	Piglets	32–34°C
2.	Weaners	28–30°C
3.	Growers/Finishers	22–26°C
4.	Pregnant/Lactating Sows	20–22°C

- Proper summer management is essential to reduce heat stress in pigs.

Housing Management

- Ventilation: The pig shed/ sty should have adequate air circulation and include fans along with provisions for tunnel ventilation systems to enhance air speed.
- Sprinklers or Misting: Install sprinklers or misting systems in the shed to spray a fine water mist into the air, which will help reduce the temperature in the pig sheds through evaporative cooling.
- Wallows: Mud wallows provide the best protection for outdoor pigs against sunburn and insects.
- Shading: Use roof insulation, shade nets, or trees to reduce solar radiation.
- Flooring: The flooring should be clean, dry, and cool so that they can lie on it and release/dissipate heat.

Water Management

- To provide clean, fresh, soft and cool (15-20°C) unrestricted water 24/7 to the animals
- Water Quality: Regularly test the quality of water by pH (6.5 to 7.5), total dissolved solids, and microbial contamination (water is free from harmful microorganisms such as E. coli: diarrhea, dehydration, especially in piglets; Salmonella spp.: Enteric infections, fever, reduced growth; Clostridium spp.: severe diarrhea, enterotoxemia; total coliforms: indicator of fecal contamination), and total dissolved solids. Weekly cleaning of the water storage tank and channels of water supply (pipelines) is necessary to prevent the development of biofilm and bacterial growth.
- Total dissolved solids are an essential quality parameter in pig production. TDS levels in drinking water for pigs should be as follows:

  TDS Levels in Drinking Water

Sr. No.	TDS (PPM)	Water Quality	Effect on Pigs
1	< 1,000	Excellent	Recommended for pigs
2	1,000 – 2,999	Good	Recommended, but monitor growth performance.
3	3,000 – 4,999	Fair	Not recommended in young pigs, it may cause diarrhea or reduced intake.
4	5,000 – 6,999	Poor	It is not recommended in pregnant, lactating, weaned, grower, and finisher pigs; it can cause reduced growth and mild health issues..
5	≥ 7,000	Unsafe	Not recommended for pigs: can lead to serious health problems.

- The drinking water of pigs is not contaminated with harmful microorganisms like E. coli. (diarrhea and dehydration, especially in piglets), Salmonella spp. (enteric infections, fever and reduced growth), Clostridium spp. (Severe diarrhea and enterotoxemia).
  - The microbial quality standards for drinking water for pigs are less than 100 total bacteria and less than 50 coliform bacteria per milliliter. If the coliform levels exceed 100 CFU/mL, this may indicate the need for chlorine treatment.
  - **Quality Standards (microbial) for pig drinking water:** During the summer, it is necessary to increase water points, such as nipple drinkers or water troughs. Thumb rule: at least One drinker per 10 pigs, while in summer it is One per 5 pigs. The sufficient flow rate of water in the nipple drinker should be 0.5–1.0 L/min for weaners, 1.0–2.0 L/min for growers/finishers, and 2.0–4.0 L/min for sows/lactating pigs. The drinkable water should be maintained at about 15–20°C, and the water tank should be in a shaded area, and the channels of the pipeline should be buried (insulated pipeline).
  - **Requirements of water:** The requirement of water in summer increased 2 to 3 times more than usual. Daily requirement of water during summer for Grower pigs: 6–8 L/day, finishers: 8–12 L/day, and lactating sows: 15–30 L/day. The water trough or nipple drinker should be placed at the pig's shoulder level. The water trough should be cleaned regularly, and any blocked or non-functional nipples should be checked daily.

Handling

- The owner/workers should avoid entering the pen during the peak heat period (10 AM to 4 PM).
- Animals should only be handled for feeding, cleaning, vaccinations, weighing, etc., during the cooler parts of the day, either early in the morning (before 10 AM) or late in the evening (after 4 or 5 PM).
- Ensure sufficient space for all pigs to lie down and move freely. Avoid overcrowding, which may lead to fighting and restlessness.
- Transport: Move the pigs during early morning or night, using well-ventilated trucks. During transit, ensure animals get adequate rest, and water should be available if the journey exceeds 8 hours.

Feeding managements

- Managing nutrients in pig feed formulations during summer is crucial for supporting their growth, reproduction, and overall health. Therefore, diets should be modified to supply all the essential nutrients in a reduced feed volume.
- **Energy density:** In the summer, due to appetite loss in animals, they consume less feed. To compensate for less feed intake, increase the dietary energy by adding fat/oil (e.g., vegetable oil, animal fat) up to 3–6% and reduce the fibre in the diet to minimise heat increment during the digestion process..
- **Protein and Amino Acids:** The excess use of protein (crude protein) in the diet of pig's increases heat increment and nitrogen waste along with overall feed cost. Reduce the crude protein while maintaining amino acid balance by supplementing with essential amino acids (Lysine, Methionine, Threonine, and Tryptophan).
- **Electrolyte Balance (Na^+, K^+, Cl^-):** Due to heat stress, animals lose electrolytes via panting and urination. Add electrolytes (Sodium, potassium, chloride, and bicarbonates) to drinking water to prevent dehydration and support recovery from heat stress.
- **Antioxidants:** During the summer, oxidative stress increases and damages cells. The following antioxidants are recommended for their various beneficial effects.

Vitamin E: antioxidant supports muscle function; Selenium: works with Vitamin E, Zinc: skin and gut health; Betaine: reduces internal heat and improves osmoregulation; and Chromium: helps control stress and supports energy use.

- **Feed Additives:** These should be used in the summer months to reduce the negative impact of heat stress on growth, health, and feed efficiency. Important feed additives include Probiotics, Organic acids (formic, lactic acid), Enzymes (phytase, protease), and Mycotoxin binders to prevent mould growth in feed during hot-humid conditions and reduce the effect of mycotoxin on animals.
- **Feeding time :** Feed should be offered during cooler parts of the day, i.e. during early morning (before 10 AM) or late afternoon (after 4 PM). Wet feeding or soaked dry feed should be offered to the pigs to improve palatability and feed intake. Split feeding (2 to 3 smaller meals) may also be practised. The pig owner should ensure that the workers provide fresh feed and remove any leftover spoiled feed immediately.
- **Water as a Nutrient!** Water is often the most essential nutrient during summer. Ensure that the water is clean, cool (15–20°C), and easily accessible to different categories of pigs with a high flow rate (2 to 4 L/min).

Labor Management

- Working schedule: Farm work should be performed during cooler parts of the day: early morning (before 10 AM) or late afternoon (after 4 PM), and animal handling, feeding, moving, and other routine activities should be avoided during peak heat from 11 AM to 4 PM.
- Minimize disturbances such as shouting, unnecessary entry into pens, mixing the pigs, changing their pens, or herding during the peak heat stress period of the day.
- Pigs should be watched for symptoms of heat stress, such as lethargy, reddish skin, and open-mouth breathing.
- Feed and Water: Workers must refill the water and check the flow rates of the nipples daily. They should promptly remove any spoiled feed and ensure that fresh feed is provided at scheduled times.

- In case of an emergency, pigs suffering from heat stroke should be immediately shifted to cooler areas, with extra fans and cool water with electrolytes should be made available for drinking to animals.
- Checklist for daily work: Critically check the following at the pig farm, like a) working of water points, b) working of cooling fans/sprinklers etc, c) feed quality, d) pigs' eating/drinking behaviour, and e) signs of stress in pigs. In case of any deficiency, take immediate action necessary for the welfare of animals.
- Rotational shifts for workers: Use rotational shifts for workers during peak summer to manage different farm activities efficiently.

Conclusions

High thermal stress in pigs adversely influences their production (slower growth rates and lower dressing percentages), reproduction (farrowing rates, reduced litter size and breeding performance in boars), and health (dehydration, heat fatigue and immunosuppression), which ultimately leads to a significant detrimental economic impact on the pig industry. To mitigate the negative consequences of heat stress on pigs, it is very imperative for the pig farmers to implement the above-stated comprehensive summer management strategies in their pig farms, which will not only increase their profit from the pig farm but also ensure a resilient pork industry in the country.

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ADAPTATION STRATEGIES OF COTTON FARMERS TO CLIMATE VARIABILITY IN KARIMNAGAR DISTRICT

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Abstract

The present study was undertaken in the Karimnagar district of Telangana to assess the adaptation strategies of cotton growers to climate variability. A total of 240 farmers were selected using an ex-post facto research design. The findings revealed that a majority of the respondents (64.83%) exhibited a medium level of adaptability, followed by high (19.33%) and low (15.83%) levels. Variables such as farming experience, landholding, family size, achievement motivation, credit and subsidy orientation, and risk orientation had a significant positive correlation with adaptability. However, age, annual income, extension contact, social participation, cosmopoliteness, and preparedness for adaptation showed no significant relationship.

Keywords: Adaptability, Profile, Cotton Growers, Ex-post Facto, Climate Variability

Introduction

Climate variability poses a significant threat to agriculture, particularly in drought-prone regions like Karimnagar. Increased frequency and intensity of droughts affect water resources, agricultural productivity, and livestock health, thereby threatening food security and rural livelihoods. For farmers dependent on rainfall, crop failure often results in household food insecurity. This study explores how cotton farmers in Karimnagar adapt to such climatic stresses, identify effective coping mechanisms, and examine key socio-economic factors influencing

adaptability. Despite various adaptation and mitigation strategies promoted by government and private agencies, limited research has focused on the actual preparedness of farmers to implement these practices. No systematic study has previously investigated the adaptability of cotton growers to climate variability in Karimnagar. Therefore, the present study was undertaken to bridge this research gap.

Methodology

The study employed an ex-post facto research design as outlined by Kerlinger (1973), which is suitable when variables have already occurred and cannot be manipulated. Karimnagar district was purposively selected due to its vulnerability to climate-induced droughts. Twelve villages across four mandals were selected, and 20 farmers from each village were randomly chosen, totalling 240 respondents.

Results and Discussion

Table 1: Distribution of Respondents Based on Adaptability to Climate Variability

Category	Score Range	Frequency	Percentage
Low	Up to 94	38	15.83%
Medium	95 - 109	158	64.83%
High	110 & above	44	19.33%
Total		**240**	**100.00%**

Mean = 102.00, SD = 8.00

The majority of farmers (64.83%) had a medium level of adaptability. This suggests that most cotton growers are partially equipped to manage climate variability, likely due to their moderate farming experience and knowledge.

Table 2: Correlation Between Selected Variables and Adaptability

Variable	Correlation (r)	Significance
Age	0.104	Not Significant
Education	-0.032	Not Significant

Farming Experience	0.176	**Significant**
Land Holding	0.150	*Significant*
Family Size	0.149	*Significant*
Annual Income	0.065	Not Significant
Achievement Motivation	0.111	*Significant*
Extension Contact	0.013	Not Significant
Social Participation	0.024	Not Significant
Cosmopoliteness	0.012	Not Significant
Credit and Subsidy Orientation	0.137	*Significant*
Preparedness for Adaptation	0.064	Not Significant
Risk Orientation	0.147	*Significant*

Significant at $p<0.05$;* Highly significant at **$p<0.01$

Key Findings:

- **Farming Experience**: Positively correlated with adaptability. Experienced farmers are better equipped with knowledge and skills to respond to climate change.
- **Land Holding**: Larger holdings provide better access to adaptive resources and technologies.
- **Family Size**: Larger families may collectively share knowledge and tasks, enhancing adaptability.
- **Achievement Motivation & Risk Orientation**: Farmers with higher drive and risk-taking abilities tend to adopt climate-resilient practices.
- **Credit and Subsidy Orientation**: Access to financial support encourages adaptation.
- Non-significant variables included age, education, income, extension contact, social participation, cosmopoliteness, and preparedness for adaptation—likely due to lack of exposure or access to training and information.

Conclusion

The study concludes that a majority of cotton farmers in Karimnagar exhibit a moderate level of adaptability to climate variability. Significant determinants of adaptability include farming experience, landholding, family size, motivation, credit access, and risk orientation. These insights can guide policymakers and extension agencies in tailoring climate-resilient programs for vulnerable farming communities.

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SYNBIOTICS IN AQUACULTURE: ENHANCING FISH HEALTH AND PRODUCTIVITY

Article ID: AG-V05-I07-29

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Abstract

Synbiotics are nutritional supplements containing probiotics and prebiotics which are used in combination to add benefits. Probiotics are increasingly being incorporated into aquaculture to promote fish health, and fish production. despite the limited research on synbiotics in aquaculture, existing studies demonstrate beneficial effects on fish, including survival, growth, feed efficiency, immune function and disease resistance. This paper summarizes some of the recent literature on synbiotics in aquaculture, examines the author's empirical research, assesses the potential benefits of synbiotics and evaluate important parameters influencing synbiotic use in fish feed. More research in this area is necessary to understand the mechanisms of synbiotics, as well as to establish supplementary dosing guidelines for synbiotics in fish feed.

Keywords: Synbiotics, Probiotics, Prebiotics, Aquaculture

Introduction

The probiotics are dietary supplements containing live microorganisms which enhances gut microbial balance of organisms (Vijayaram and Kannan, 2018). Prebiotics are non-digestible food components that help beneficial bacteria in the colon grow and thrive, supporting a healthy gut (Okey *et al.*, 2018). Synbiotics are combination of probiotics and prebiotics, enhances health and well-being of host (Das *et al*., 2017). The prebiotic nourishes the probiotic, enhancing its survival and function, promoting a balanced gut microbiome (Mehrabi *et al*., 2011). By boosting the growth and activity of beneficial gut bacteria, synbiotics promote health of organisms

(Cerezuela *et al*., 2011; Das *et al*., 2017). Synbiotic may influence digestive enzymes in fish which subsequently may improves digestion and absorption of nutrients allowing more growth and feed utilization. The utilization of prebiotics and probiotics is an emerging and alternate treatment, showing potential as an effective biological regulatory approach and developing into a key aspect of the aquaculture management in promoting healthy development and disease tolerance (Rombout *et al*., 2010; Cerezuela *et al*., 2011)**.**

Mechanisms of Synbiotics

Synbiotics are the combination of prebiotics and probiotics that work synergistically to amplify health benefits in the host organism (Mohapatra *et al*., 2013), support the growth and establishment of live probiotic microorganisms in the gastrointestinal tract, improving their effectiveness and longevity (Daniels *et al*., 2010). Evidence indicates that synbiotics can improve crab health by enhancing disease resistance, stimulating growth performance, increasing feed utilization, refining carcass composition, maintaining gastric morphology, and elevating digestive enzyme activity (Hassan *et al*., 2014), similar effects have also been observed in Nile tilapia (*Oreochromis niloticus*) (Cavalcante *et al*., 2020). Lysozyme activity, a key component of the innate immune system that helps protect fish against pathogenic infections, was significantly higher in fish fed a synbiotic diet compared to those given diets containing only individual prebiotics (Ye *et al*., 2011).



Benefits of synbiotics in aquaculture

The use of synbiotics in aquaculture is a relatively recent, it has received large amounts of considerable attention due to the potential benefits previously observed in endothermic animals (Ringo *et al*., 2016). Mehrabi *et al*. (2011) reported significant improvements in body weight gain when fish were fed with diets containing synbiotics for 60 days. The weight gains for the fish in groups with synbiotics were 50%, 59%, and 53% higher than the control group, respectively. The synbiotics promotes the fish growth, digestive enzyme, disease resistance, Survival rate and immune system (Fig. 1).

Adding 1-3% inulin (prebiotic) to Beluga sturgeon's diet improved growth performance, including: growth, feed utilization, body weight gain. According to (Isolauri *et al*., 2002; Paulina and Katarzyna, 2018), synbiotics stimulate the immune system in two ways. Application of prebiotic and probiotic alone or in combination releases immunostimulant that improves the immune systems**.** The beneficial microbes from synbiotics colonize the gut wall, multiply, and upon death release antigens that stimulate the immune system when absorbed (Okey *et al*., 2018). The usage of a synbiotic combination of pediococcus acidilactici and galacto-oligosaccharides positively affected various characteristics of the innate immune response, skin mucus parameters, and disease resistance in rainbow trout; as well as increased antioxidant enzyme activity in fish (Hoseinifar *et al*. 2015). As synbiotic therapeutic approach could be a suitable substitute for pathogen control and management the efficiency of synbiotics regarding protection against disease causing agents assessed through a challenge study.

Synbiotics, a combination of probiotics and prebiotics, enhance gut health by boosting beneficial microbes, improving digestion and nutrient absorption, facilitating fermentation, and supporting vitamin synthesis, such as vitamins A and K, ultimately benefiting humans and other animals **(**Okey *et al.,* 2018). Synbiotics in aquaculture have been shown to improve water quality and boost production by enhancing organic matter breakdown, increasing oxygen levels, removing waste products, and reducing algae growth (Okey *et al.,* 2018).

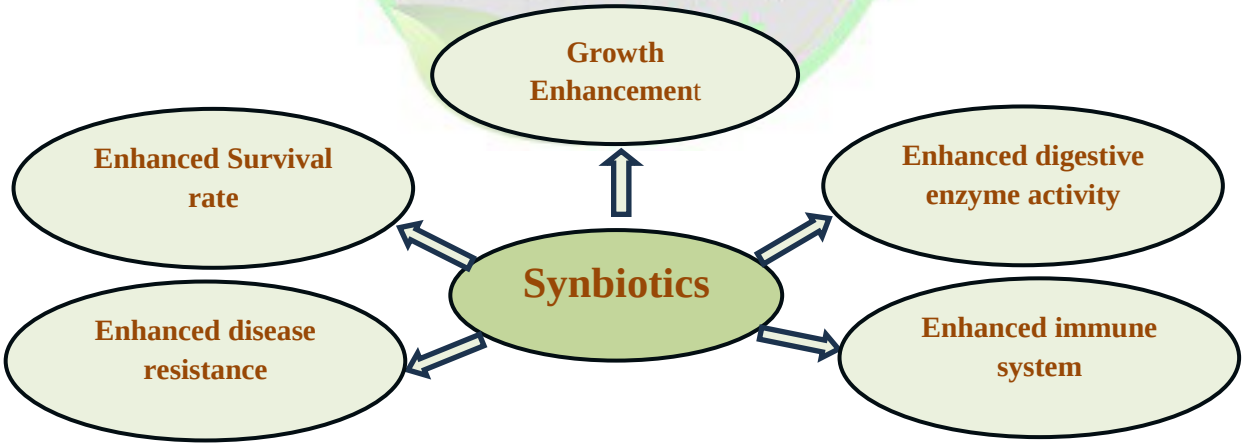


Fig.1. Benefits of Synbiotics

Challenges and Future Directions

Practical application of synbiotics must undergo a well-defined and precise methodology. This process requires through characterization under rigorous experimental conditions,

standardized selection criteria, a reliable framework for implementation and consistent production along with ongoing evaluation and refinement. Field testing of synbiotics holds significant importance, as outcomes achieved under laboratory conditions may not always be applicable or effective in actual aquaculture settings. Additionally, in many studies, the effectiveness of additives is seldom assessed on large-scale commercial farms or under the standard production conditions relevant to the aquatic species investigated (Amenyogbe *et al*., 2020). Unit production costs are reduced by 44% as the result of probiotic application in larval *Litopenaeus vannamei* with 6% increase in total production cost, resulted in higher survival rate (Penalosa *et al*., 2021). The use of synbiotics and their components in aquaculture may be constrained by economic considerations. In intensive aquaculture operations, feeding costs represent a major expenditure, often comprising 60-80% of the overall operational budget. Studies evaluating the use of synbiotics in aquaculture have consistently shown improved economic efficiency over control diets, especially when aquatic species are exposed to stressors like high stocking densities or during the reproductive phase (Srirengaraj *et al*., 2023).

Conclusion

Synbiotics have become an effective response within the aquaculture industry, providing several benefits in relation to fish health, growth and disease resistance. Synbiotics incorporate probiotics and prebiotics, to create synergistic effects in gut health by improving digestion and immune resistance in the gut. In various fish species, synbiotics have been used to improve growth performance, feed utilization and disease resistance, while to an even greater extent, synbiotics improved water quality and decreased production costs. A better understanding of the mechanism of synbiotics, within algal species, fish species, and the development of commercially standardized guidelines, are worth further research effort. Cost assessments and field testing are additional considerations required to apply synbiotics within aquaculture. Synbiotics could potentially serve a role in promoting sustainable aquaculture, with health benefits toward fish production and mitigating some of the environmental concerns involved in aquaculture. The aquaculture sector can evolve towards a more sustainable and environmentally friendly future by the use of synbiotic benefits. Further studies are necessary to explore the full potential of synbiotics in aquaculture and to overcome the challenges associated with their use.

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GOLDEN DROPS: A SIMPLE GUIDE TO MARKET HONEY

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Introduction

India's honey market remains largely unorganized, with most sales occurring through informal roadside stalls and local shops. Effective marketing makes certain that these important commodities are sold at fair prices and make a substantial contribution to the sustainability of agriculture and rural livelihoods. The greater productivity of species like the honeybee *Apis mellifera* as compared to native bees allows for more commercial-scale beekeeping and the harvesting of a variety of hive goods. Products like bee venom, royal jelly, and propolis are especially valuable in the pharmaceutical and cosmetic sectors, but they remain underutilized in India due to a lack of awareness, technology, and organized supply chains.

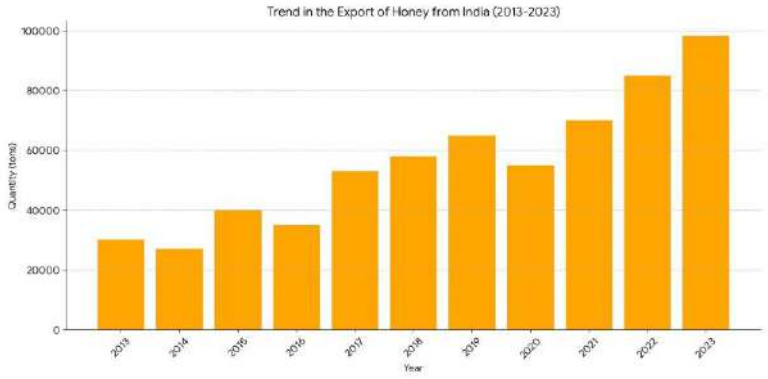


Fig 1: Export of honey from India (2013-2023)

The current state of hive product marketing, both domestically and globally, is examined in this article.

It emphasizes the importance of high-quality maintenance, appealing packaging, clear labeling, and novel marketing techniques, while also defining the roles played by different stakeholders such as government organizations, cooperatives, NGOs, and commercial businesses. Through sustainable apiculture, the unit hopes to empower beekeepers and entrepreneurs to access larger markets, improve income generation, and support rural development.

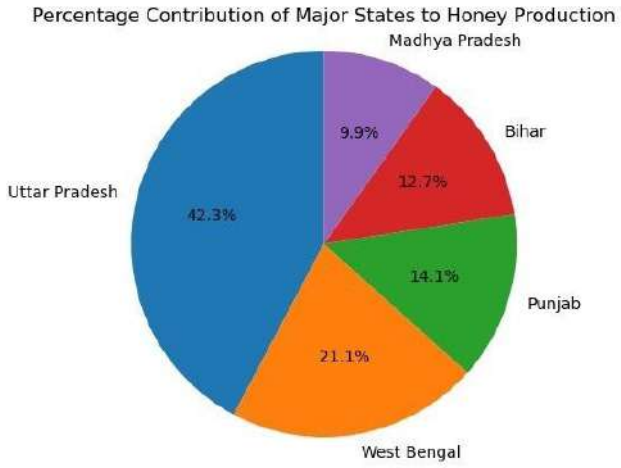


Fig 2: Honey production in major states of India

Buzzing into the Indian market

The majority of honey sales in India continue to occur through local shops and informal roadside kiosks since the market is still largely unorganized. The market has, however, begun to be organized by initiatives such as honey processing facilities, quality certification (AGMARK, BIS), and promotional events, thanks to increasing backing from government organizations like the Central Bee Research and Training Institute (CBRTI), the Khadi and Village Industries Commission (KVIC), and the National Bee Board (NBB). To strengthen this developing industry, the Indian government has launched the ”Formation of 10,000 Farmer Producer Organizations (FPOs)” plan, which has assigned 100 FPOs exclusively for Beekeepers/Honey Producers to TRIFED (14), NAFED (60), and NDDB (26) in order to carry out national Beekeeping and Honey Mission (NBHM) activities. As of now, 77 of the 105 FPOs that the National Bee Board (NBB) has allocated have been established or registered. In addition, the Ministry of Agriculture Farmers Welfare has introduced the ”Madhukranti Portal” in order to create complete traceability records for honey and other bee hive products.

According to the National Bee Board's records, there are now over 1.934 million honey bee colonies and about 12,699 licensed beekeepers. The NBHM has approved a total of 102 projects with funding of Rs. 133.31 crores. Under the leadership of the National Bee Board (NBB), India's beekeeping industry has seen remarkable growth; as of the 2021–22 agricultural year, there were around 12,699 registered beekeepers managing over 1.934 lakh honey bee colonies. With a significant output of 133,200 metric tonnes, India has become one of the top honey-producing and exporting nations in the world thanks to its strong infrastructure. More than half of India's honey production is exported to international markets, with shipments totaling around 74,413 metric tons worth 1,221.17 billion in 2021–22 to over 83 countries. Key global markets include the United States, Saudi Arabia, the United Arab Emirates, Bangladesh, and Canada. Several distinct and region-specific varieties dominate India's export portfolio, including:

- Mustard honey
- Eucalyptus honey
- Lychee honey
- Sunflower honey
- Pongamia honey
- Multi-flora Himalayan honey
- Acacia honey
- Wild flora honey

These varieties reflect the ecological diversity of India's flora and its vast potential for niche, value-added honey markets globally

More Than Just Honey

1 **Wax from bees**

In India's apiculture sector, beeswax is the second most traded commodity. It is mostly used in comb foundations, but it is also used in cosmetics, candles, and polishes. Value addition remains constrained, indicating untapped opportunity, even when processed by CBRTI and private producers.

2 **Pollen**

Worldwide, pollen is a highly prized hive product because of its high protein content and health benefits. Despite the fact that its marketing and collection are still in their infancy in India,

with the majority of pollen being recycled for use within the colony, growing health awareness suggests a large commercial opportunity.

3 Propolis

Despite its significant worldwide value and benefits in wound healing and dental care, there is minimal awareness of propolis in India, a resinous substance known for its antibacterial and anti-inflammatory effects.

4 Bee Venom

Specialized machinery is used to collect bee venom, a valuable substance used in the treatment of diseases like rheumatoid arthritis. However, despite its high global market value and usage in apitherapy and medicines, India's commercial output is insignificant.

5 The Royal Jelly

In states like Punjab, the commercialization of royal jelly, known for its nourishing and revitalizing effects, is just getting started. Its expanding health consciousness in India and thriving global market point to significant potential future demand.

6 Bee Brood

Due to its high protein content, bee brood, which includes larvae and pupae, is consumed as a delicacy in Southeast Asian nations. Although it is not consumed or commercialized in India because of dietary preferences and the need to maintain colony strength, it has export potential if it is properly harvested and processed.

Sweet success needs smart marketing

With more than 50,000 downloads, the National Bee Board's BeeBase App offers a wealth of information on beekeeping practices, illness control, and market prices. This app provides comprehensive resourceson beekeeping techniques, disease management, and market prices. It has been downloaded by over 50,000 beekeepers across India. Similarly, the BeeZee App,developed by The Hive, offers training modules, hive management tips, and disease identification assistance. The BeeZee App, which minimizes reliance on middlemen by connecting beekeepers directly with purchasers, also offers training modules, hive management advice, and a marketplace.The app currently has over 10,000 active users. Beekeepers have been able to sell directly to national and international purchasers via online markets such Agrimarket and Indiamart, which has helped them get better prices for their goods. Additionally, online

training and certification programs have taught over 30,000 beekeepers about scientific beekeeping techniques, including hive care, honey extraction, and pest management.

Future challenges

The Indian apiculture industry continues to struggle with issues like a shortage of qualified workers, cheap market prices for certain goods, insufficient working capital, and the sluggish uptake of modern technologies. In order to realize the full economic potential of hive products, it is imperative that there be a sustained emphasis on quality control, appealing packaging, informative labeling, and creative marketing strategies. By strengthening the value chain, raising consumer awareness, and utilizing digital platforms, India may further empower its beekeepers, boost income generation, and make a significant contribution to rural development via sustainable apiculture. The transition from disorganized sales to a organized, worldwide competitive sector for a wide variety of hive products is well underway, indicating a bright future for beekeeping in India. However, marketing remains a persistent challenge for Indian beekeepers. A large portion of hive products is sold in an unorganized manner—via roadside vendors or small local shops—without quality certification, branding, or consumer education. This informal setup not only limits the profitability for beekeepers but also undermines consumer trust and reduces market reach. Unlike agricultural commodities like grains or milk, honey and its byproducts often lack standardized marketing channels and government-backed pricing mechanisms. This results in beekeepers receiving inconsistent or unfair returns for their efforts.

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INTEGRATED FISH-SEAWEED CULTURE SYSTEMS: A SUSTAINABLE APPROACH TO AQUACULTURE PRODUCTION

Article ID: AG-VO5-I07-31

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Abstract

The expansion of intensive aquaculture practices, such as finfish and shrimp farming, has raised serious environmental concerns due to the release of nutrient-rich effluents into coastal ecosystems. This nutrient discharge can exceed the natural capacity of receiving waters, leading to ecological degradation. A promising solution involves integrating traditional fed aquaculture with extractive systems like seaweed and shellfish cultivation. In these integrated setups, waste nutrients from fish or shrimp are absorbed and utilized by seaweeds and filter feeders, which act as natural biofilters. This approach not only helps maintain water quality but also produces additional valuable crops, improving economic returns and sustainability. Moreover, as regulations on aquaculture effluents become more stringent worldwide, integrated multi-trophic systems offer a cost-effective means of compliance. By adopting such practices, aquaculture operations can reduce their environmental footprint, enhance resource efficiency, and align with broader coastal management objectives.

Introduction

Modern aquaculture faces a pressing challenge: how to produce large quantities of high-quality seafood while reducing the environmental footprint of intensive farming systems. Conventional land-based fish culture systems require high rates of water exchange to prevent the buildup of toxic metabolic wastes, particularly ammonia. Although bacterial biofilters are commonly used to convert ammonia into less harmful forms, these systems still discharge significant quantities of nutrients into coastal waters. As the industry evolves, integrated fish-seaweed culture systems have emerged as an innovative solution to improve nutrient

management and enhance sustainability. By combining fish production with seaweed biofiltration, aquaculture facilities can transform nutrient-rich waste streams into valuable biomass while improving water quality for cultured fish.

Seaweed Biofilters: Nature's Nutrient Strippers

Seaweeds such as *Ulva lactuca* (commonly known as sea lettuce) are highly effective at removing dissolved nutrients from water. In integrated mariculture systems, fish or shrimp excretions serve as fertilizers for seaweed, which rapidly assimilates ammonia and other nutrients into algal biomass. This process not only purifies the water but also produces a secondary crop with commercial value. Ulva is rich in protein and can be used as feed for herbivorous aquaculture species like abalone and sea urchins. Additionally, seaweed has growing markets in human nutrition, health supplements, and cosmetics.

Previous small-scale experiments by Neori and colleagues demonstrated the feasibility of reusing seawater purified through seaweed biofilters. However, scaling these systems to semi-commercial production posed new technical challenges, including maintaining consistent nutrient removal during periods of low light and cooler temperatures.

System Design and Experimental Setup

With support from the Israeli Ministry for Infrastructure and the European Union, researchers developed an intensive, recirculating integrated culture system to assess the performance of seaweed biofilters at larger scales. The experimental facility in Eilat, Israel, incorporated a 40,000-liter fish tank stocked with 500 kilograms of gilthead sea bream (*Sparus aurata*). The system was designed to recirculate water through multiple modules: an upstream shellfish rearing unit and a downstream seaweed biofilter.

To maintain water quality, effluent from the fish tank was first mechanically screened to remove particles larger than 0.5 millimeters before passing through the biofilter. Because abalone require very high rates of clean water exchange, their tanks were excluded from the recirculation loop. However, abalone and sea urchins were fed with the seaweed produced in the biofilter, further enhancing system integration and nutrient utilization.

The biofilter itself was constructed from plastic foil and a metal frame and designed to keep seaweed in suspension through continuous aeration. Outflows were covered with mesh to retain algal biomass, and harvested seaweed was collected through a drainage system that discharged into an underground collection box.

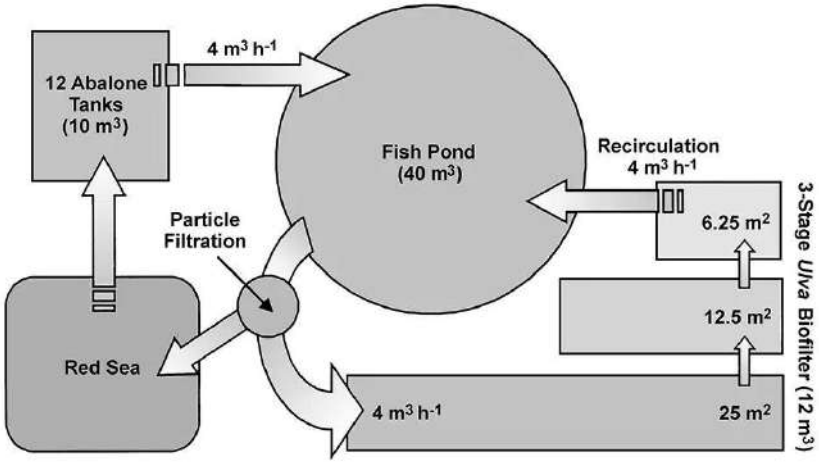


Fig. 1: The integrated system recirculated water among abalone tanks, the primary fish pond and a series of biofilters.

Optimizing Nutrient Removal

One of the primary goals of the experiment was to balance nutrient removal efficiency and seaweed productivity. Researchers observed that when supplied with higher nutrient loads, Ulva removed more nitrogen in absolute terms but with lower efficiency (i.e., a smaller proportion of the available ammonia was assimilated). Conversely, lower nutrient concentrations supported higher removal efficiencies but reduced the overall rate of nutrient uptake.

To address this tradeoff, the biofilter was subdivided into three sequential tanks, each with a 50% size reduction compared to the previous tank. This configuration enabled high removal rates in the early stages while maintaining optimal ammonia availability and efficiency in the later stages. The system was designed to produce seaweed with consistently high protein content, which is essential for its use as aquaculture feed.

Researchers also recognized that ammonia removal by Ulva is partly light-dependent. To maximize nutrient uptake during daylight hours, fish were fed to satiation in the morning, resulting in peak excretion during periods of maximum solar irradiance. Automated sensors monitored temperature, pH, water flow, and dissolved oxygen continuously, with weekly sampling of ammonia concentrations.

Performance and Results

Throughout the autumn and winter months—typically a challenging period for seaweed growth due to lower light and temperature—the biofilter maintained robust performance. The system produced Ulva with a protein content averaging 34% of dry weight and a fresh biomass yield of 117 grams per square meter per day. This yield is equivalent to producing roughly 36 kilograms of seaweed each week, enough to sustain approximately 3 kilograms of abalone growth.

During daylight hours, ammonia removal reached a maximum of 3.2 grams per hour with efficiencies exceeding 95%. Although removal rates decreased in the absence of light, the biofilter still achieved over 45% efficiency at night. By recirculating 50% of the fish tank effluent through the biofilter, the system reduced the overall discharge of ammonia into the environment by more than 30%.

Importantly, the integrated system naturally buffered water quality parameters. Carbon dioxide produced by fish respiration was partially absorbed by photosynthesizing seaweed, helping to maintain pH within safe limits. Dissolved oxygen levels were similarly stabilized by daytime photosynthesis, supporting fish health and reducing stress.

Thermal Management with Greenhouses

Maintaining optimal temperatures during winter was another critical aspect of system design. The fish tank was enclosed in a greenhouse similar to those used in intensive desert aquaculture operations, helping conserve heat and exclude unwanted algal growth. In January, a transparent greenhouse cover was also added to the biofilter tanks, which led to a noticeable increase in water temperatures. Warmer recirculated water helped sustain seaweed productivity during colder periods and improved overall energy efficiency. However, due to the scale of the experiment, researchers could not replicate the system to confirm whether this temperature rise resulted in faster fish and seaweed growth.

Sustainability and Commercial Potential

The integrated fish-seaweed culture system demonstrated a range of environmental and economic benefits. The co-production of fish and seaweed utilizes the complementary roles of heterotrophic consumers and autotrophic producers. This synergy improves nutrient use efficiency, reduces environmental discharge, and generates additional revenue streams. Seaweed biomass can be marketed for aquaculture feeds, health foods, and specialty products, offsetting

the costs of biofiltration infrastructure. Moreover, recirculation helps limit the introduction of pathogens and fouling organisms, contributing to improved biosecurity.

Researchers believe that scaling up the proportion of recirculated water and enlarging the biofilter area could further reduce water consumption and increase seaweed yields. This approach holds promise not only for gilthead sea bream but also for a wide variety of finfish and shellfish species in land-based systems.

Conclusion

As aquaculture continues to expand to meet global seafood demand, integrated fish-seaweed culture systems offer a compelling model for sustainable production. By transforming nutrient-rich effluents into valuable biomass, these systems address two critical challenges—waste management and resource efficiency. The successful operation of the Eilat facility demonstrates that integrated systems can maintain excellent water quality, reduce environmental impacts, and improve profitability even during less favorable seasons. Continued innovation and adoption of such integrated approaches will be essential for building a more sustainable and resilient aquaculture industry in the decades to come.

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DRONE TECHNOLOGY AND ITS IMPACT ON AGRICULTURAL INNOVATION

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Introduction



In recent years, agriculture has experienced a technological revolution that is reshaping traditional practices and paving the way for more efficient, sustainable, and data-driven farming methods. Among the various technological advancements, drone technology—also known as Unmanned Aerial Vehicles (UAVs)—has emerged as one of the most transformative tools for modern agriculture.

Equipped with advanced sensors, high-resolution cameras, and GPS technology, drones are now providing farmers with real-time insights that were once difficult or impossible to obtain. These aerial tools enable faster decision-making, better crop monitoring, and precise resource management, all of which contribute to increased productivity and reduced environmental impact.

As the global population continues to rise and the demand for food production intensifies, agricultural drones offer promising solutions to address critical challenges. This article explores the many ways drones are used in agriculture, the benefits they bring, the challenges they face,

and their future role in transforming farming practices worldwide.

How Drones Are Used in Agriculture

Drone technology has opened up a wide range of applications in agriculture, from monitoring crop health to managing livestock. Their flexibility and precision make them an indispensable part of modern farming systems.

A. Crop Monitoring and Management



One of the most common uses of drones in agriculture is monitoring crop conditions. By flying over fields and capturing high-resolution images, drones provide a bird's-eye view of large areas of farmland. These images allow farmers to assess plant health, detect diseases, identify pest infestations, and determine if crops are receiving the nutrients they need.

1. **Real-Time Decision Making**: Drones collect and transmit data in real time, enabling farmers to make quick and informed decisions about when and where to irrigate, fertilize, or apply pesticides. This precision leads to more efficient use of resources and helps boost yields.
2. **Early Problem Detection**: Thermal and multispectral imaging from drones can reveal issues such as water stress, fungal infections, or nutrient deficiencies long before they become visible to the human eye. Early detection means faster intervention and better outcomes.

B. Precision Spraying

Drones are also revolutionizing how farmers apply agricultural inputs like fertilizers, herbicides, and pesticides. Unlike traditional machinery, drones can spray exactly where needed, minimizing chemical use and maximizing effectiveness.

1. **Targeted Application**: Instead of treating an entire field uniformly, drones can focus only on problem areas, reducing costs and limiting environmental damage. This is especially important for sustainable farming practices.
2. **Efficient and Safe Use of Chemicals**: Drones reduce the risk to human health by minimizing farmers' direct exposure to chemicals. They are also ideal for spraying in hard-to-reach or uneven terrain, where large machinery may struggle.

C. Mapping and Surveying: Detailed mapping is crucial for land management and planning. Drones provide highly accurate maps and models that help farmers understand their fields better.

1. **Topographic and Soil Mapping**: Drones can survey large areas quickly and generate 3D maps of field topography. These maps help plan irrigation systems, drainage solutions, and planting patterns based on elevation and soil composition.
2. **Field Boundary and Zoning Analysis**: By identifying field boundaries and variations in soil conditions, drone-generated maps support zone-based management, a key aspect of precision agriculture.

D. Livestock Monitoring

Beyond crops, drones are being used to manage livestock operations more efficiently, especially on large farms and ranches.

1. **Remote Monitoring of Herds**: Drones equipped with cameras and GPS can locate and monitor animals over wide areas. This reduces the time and labor needed for manual checking.
2. **Health and Behavior Analysis**: With thermal imaging, drones can detect signs of illness, monitor heat cycles, and observe grazing patterns, all of which contribute to better animal welfare and more productive livestock.

Benefits of Agricultural Drones

The benefits of drone technology in agriculture go far beyond convenience. They significantly improve farm management, increase productivity, and support sustainability.

A. Greater Efficiency

Drones make it easier and faster to collect large amounts of valuable data.

1. **Time-Saving**: Manual field inspection can take hours or even days. Drones can cover the same area in minutes, providing fast, reliable information.
2. **Labor Cost Reduction:** With fewer people needed for field surveys and inspections, drones help reduce labor costs while improving accuracy.

B. Boosting Precision Agriculture

Precision agriculture involves managing fields based on data rather than averages. Drones play a critical role in this approach. Drones provide images and data that allow farmers to customize treatments for specific areas within a field. Instead of applying fertilizer evenly across an entire field, drones help apply it only where it's needed most.

1. **Better Resource Management**: Water, fertilizer, and pesticides can be used more effectively, saving money and reducing environmental impact.
2. **Higher Yields:** Healthier plants and more efficient input use lead to better yields and higher-quality crops.
3. **More Frequent Monitoring:** Unlike satellite images, which may be infrequent or affected by weather, drone images can be captured regularly and under various conditions.

C. Accurate Use of Chemicals

Drones support the precise application of agrochemicals, which helps address overuse and pollution problems.

1. **Spot Treatments:** Treating only the areas that need attention avoids unnecessary chemical use and reduces environmental contamination.
2. **Soil Health Protection:**

Unlike heavy tractors, drones don't compact the soil, preserving soil structure and fertility.



D. Flexible and Accessible

Drones are highly adaptable to different farming environments.

1. **Access to Remote or Difficult Terrain**

Farms with hills, wetlands, or other hard-to-reach areas benefit greatly from drone surveillance.

2. **Suitable for All Farm Sizes**

Whether it's a smallholder farm or a large agribusiness, drones offer scalable solutions to fit any operation.

Challenges and Considerations

Despite their advantages, agricultural drones are not without challenges. Several barriers must be addressed to ensure widespread adoption.

1. Legal Rules and Regulations

Drone use is subject to airspace laws and safety guidelines.

a. **Compliance with Aviation Laws**

Farmers must follow regulations regarding where and how drones can be flown, which can vary from country to country.

b. **Licensing and Training**

In many places, drone operators need specific certifications or training, which may be a burden for small or remote farms.



2. Data Privacy and Management

While drone data is incredibly useful, it also raises important concerns.

a. **Privacy Concerns**

Aerial data collection can lead to concerns about surveillance and the privacy of neighboring properties or communities.

b. **Data Storage and Analysis**

Managing the vast amount of data collected by drones requires secure storage systems and advanced analytics tools. Farmers may need help interpreting this data and integrating it into their farm management systems.

3. Cost and Investment

The financial aspect is a key consideration for many farmers.

a. **High Upfront Costs**

Purchasing a drone, along with necessary software and training, represents a significant investment.

b. **Return on Investment**

Farmers must evaluate whether the benefits will justify the costs, especially in regions where profit margins are thin or technology support is limited.

Looking Ahead: The Future of Agricultural Drones

As technology continues to evolve, drones are expected to become even more valuable and accessible.



A. Better Technology

1. **Integration with Smart Farming Systems**

When combined with IoT devices, weather sensors, and satellite data, drones can offer a more complete view of the farm ecosystem.

2. **Advanced Automation**

Drones will become increasingly autonomous, able to fly programmed routes, avoid obstacles, and return home automatically after completing tasks.

B. Ongoing Research and Innovation

1. Enhanced **Performance**

Research is focusing on better battery life, longer flight times, improved image resolution, and faster data processing.

2. **Collaborative Development**

Partnerships between researchers, tech companies, and farmers will help create drones tailored to specific agricultural needs.

C. Ethics and Sustainability

1. **Responsible Usage**

Drones must be used in ways that protect natural ecosystems and respect the privacy and rights of individuals.

2. **Building Trust**

Transparency and accountability in how drone data is used will help build trust and encourage adoption across communities.

Conclusion

Drone technology is rapidly becoming a cornerstone of modern agriculture. It provides farmers with the tools they need to make smarter decisions, optimize resources, and improve both productivity and sustainability. However, successful integration of drones into agriculture will depend on overcoming challenges such as regulatory compliance, cost barriers, and data management concerns. Governments, agricultural organizations, and technology providers must work together to provide education, support, and infrastructure to help farmers make the most of this powerful tool.

Looking ahead, drones will continue to evolve and play a vital role in shaping the future of food production. As climate change, population growth, and resource scarcity put pressure on global agriculture, drones offer an innovative solution to build a more efficient, ethical, and sustainable farming system for generations to come.

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RESTORING BALANCE: THE ECOLOGICAL IMPACT OF MPAS ON DEGRADED MARINE HABITATS

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Abstract

Marine ecosystems are under growing pressure from human activities such as overfishing, habitat destruction, pollution, and climate change. These impacts have severely degraded critical habitats like coral reefs, mangrove forests, and seagrass meadows, threatening marine biodiversity and the benefits these ecosystems provide. Marine Protected Areas (MPAs) have become an essential approach to help reverse this damage. By limiting harmful activities in specific zones, MPAs allow ecosystems to recover their natural structure and function. This review explores how MPAs support the recovery of degraded marine habitats by enhancing biodiversity, improving habitat complexity, and restoring ecological interactions such as predator-prey balance and nutrient cycling. Research shows that well-managed MPAs can significantly boost fish populations, increase species diversity, and support the return of key ecological functions. However, the success of MPAs depends on several important factors, including the size and age of the protected area, the level of enforcement, and how involved local communities are in management. MPAs are not without challenges—climate change, poor governance, and social resistance can all limit their effectiveness. Even so, when integrated into wider conservation and climate strategies, MPAs offer a powerful tool to restore ocean balance and resilience.

Keywords: Marine Protected Areas; Biodiversity Recovery; Ecosystem Resilience; Ocean Conservation; Fisheries Management

Introduction

Marine habitats worldwide are changing rapidly due to the combined effects of stresses caused by humans. Seagrass meadows, mangrove forests, coral reefs, and estuarine ecosystems

have all seen substantial degradation over the past 50 years, which has reduced ecosystem services and caused a collapse in biodiversity (Jackson et al., 2001; Lotze et al., 2006). Marine Protected Areas (MPAs) have become a key part of marine conservation in response to this dilemma. When well-planned and run, MPAs can protect areas of the ocean that can help ecosystems recover, restore their functions, and keep marine species alive (Lester et al., 2009; Edgar et al., 2014).



Ecological Functions of MPAs in Habitat Recovery

1. **Biodiversity Recovery and Species Reassembly**

MPAs mitigate human stresses, allowing species to rebound in quantity and diversity. Meta-analyses demonstrate that biomass is much higher in well-enforced MPAs than in exploited regions, frequently by several hundred percent. Intact predator and herbivore populations help to stabilize ecosystem functions and sustain trophic balance (Lester et al., 2009; Edgar et al., 2014).

2. **Habitat Regeneration and Structural Complexity**

Protection from physical disruptions allows habitats like coral reefs and seagrasses to regain their three-dimensional structure, which is critical for sustaining species diversity. According to Graham and Nash (2013), structural complexity has a positive association with species diversity and ecological resilience. Natural recolonization and increased sediment accretion have occurred in mangrove systems following the cessation of wood harvesting and stabilization of the shoreline (Duke et al., 2007).

3. **Trophic Cascades and Functional Restoration**

MPAs are frequently used to return important taxa to their functioning roles. Herbivorous fish, for example, are essential for coral reef resiliency because they regulate macroalgal growth. The

recovery of parrotfish in Caribbean MPAs has resulted in greater coral recruitment and decreased algal competition (Mumby et al. 2006). The restoration of top-down control systems is critical to long-term ecological stability.

4. **Spillover and Connectivity**

MPAs serve as reproductive reservoirs, feeding larvae and migrating adults to surrounding habitats, which is referred to as the spillover effect. Incorporating MPAs into larger seascape management frameworks promotes conservation and fisheries goals by fostering ecological connection (Gell & Roberts, 2003).

Causes of Marine Habitat Degradation

1. **Overexploitation and Destructive Fishing Practices**

Unsustainable fishing is a major contributor to the destruction of marine habitats. Target species are reduced by overfishing, which also affects trophic connections and causes predator-prey relationships to break down. Bottom trawling, blast fishing, and cyanide use are destructive techniques that directly harm reef structures, seagrass beds, and benthic substrates (Pauly et al., 2005; Halpern et al., 2008).

2. **Coastal Development and Land-Based Pollution**

The growth of coastal populations has resulted in substantial coastline change. Infrastructure development, land reclamation, and dredging all contribute to sedimentation, which suffocates benthic animals and decreases light penetration (Islam & Tanaka, 2004). Furthermore, eutrophication, hypoxia, and toxic algal blooms are caused by nutrient enrichment from untreated sewage and agricultural runoff, especially in semi-enclosed areas (Breitburg et al., 2018).

3. **Climate Change and Ocean Acidification**

Ocean temperatures have risen due to anthropogenic CO_2 emissions, which have also caused more stratification and acidification. These alterations raise the frequency of coral bleaching episodes and interfere with physiological functions in marine life (Hoegh-Guldberg et al., 2007). Ocean acidification affects the calcification rate of reef-building corals, mollusks, and other planktonic species, endangering the structural integrity of reef ecosystems (Doney et al., 2009).

4. **Biological Invasions**

Global shipping and aquaculture operations have brought a large number of non-native species into new habitats.

These invaders often outcompete native beings, disrupt food web dynamics, and impair habitat quality (Molnar et al., 2008).

Factors That Influence Ecological Success

1. **Protection Level and Compliance**

The level of legal protection is an important factor of MPA success. Compared to multiple-use MPAs, no-take reserves typically produce greater ecological returns (Edgar et al., 2014). But these effects are only achieved with severe enforcement and community compliance (Gill et al., 2017).

2. **Size and Age**

Larger MPAs offer higher habitat diversity and better buffering for biological processes. Older MPAs build ecological advantages over time, requiring decades to recover slow-growing species and complicated interactions (Claudet et al., 2008).

3. **Habitat Quality and Ecosystem Type**

The initial conditions influence recovery pathways. Compared to MPAs in significantly changed states, those in systems that are comparatively intact or somewhat deteriorated recover more quickly. For example, coral reefs may fail to regenerate if their structural complexity and coral cover fall below ecological thresholds (Hughes et al., 2010).

4. **Governance, Participation, and Local Knowledge**

Incorporating local stakeholders into MPA design and management improves compliance and adaptability. Co-management models have proven effective in places such as the Philippines and the Pacific Islands (Ban et al., 2011). Traditional ecological information supports scientific monitoring, enhancing the management process.

Limitations and Challenges

- **Climate-Induced Stressors**

MPAs are incapable of safeguarding ecosystems from global dangers including rising sea levels, warmer oceans, and acidification of the ocean. Coral bleaching and mass mortality episodes persist in MPAs, underscoring the necessity for global emissions reduction in conjunction with local conservation efforts (Bruno & Selig, 2007).

- **Socioeconomic and Political Barriers**

Implementation can result in temporary economic detriment for local residents, particularly in areas where livelihoods are intricately linked to extractive activities. The effectiveness of MPAs

is dependent on equitable benefit-sharing, compensation systems, and community empowerment (Mascia et al. 2010).

- **Enforcement Deficits and Paper Parks**

Many MPAs only exist on paper around the world. These places fail to accomplish ecological objectives in the absence of proper financing, manpower, and political will (Agardy et al., 2011). Legal enforcement tools, community rangers, and satellite surveillance are necessary for assuring compliance.

- **Knowledge Gaps and Monitoring**

Monitoring is generally infrequent, methodologically unreliable, and inadequately supported. Long-term ecological data are vital for assessing efficiency and guiding adaptive management. Promising instruments for addressing these deficiencies include developments in automated reef monitoring structures (ARMS), environmental DNA (eDNA), and remote sensing (Fox et al., 2014).

Conclusion

In order to mitigate the destruction of maritime habitats and restore ecological equilibrium, maritime Protected Areas are an essential intervention. Although they are not a panacea, MPAs that are well-designed, equitably administered, and efficiently implemented have the potential to improve the functioning of ecosystems, reverse biodiversity loss, and improve adaptability to climate change. In the Anthropocene, MPAs will only be successful if they are part of larger ocean governance systems based on science and involving the community.

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FROM HIVES TO HIGHWAYS: INDIA'S JOURNEY THROUGH THE SWEET REVOLUTION

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Introduction

Honey production, also known as apiculture or beekeeping, involves managing honeybee colonies to harvest honey and production of other bee products. Bees collect nectar and honeydew from flowers, which they transform into honey through a process of refinement and evaporation in their hives. Beekeepers then harvest the finished honey from the hive. India has seen many important revolutions in its food sector, like the White Revolution for milk, Green Revolution for farming, and Yellow Revolution for edible oils. In 2016, Prime Minister Narendra Modi called for the Sweet Revolution to help double farmers' income by 2024. This mission was started to promote beekeeping and related activities. Also known as the Honey Mission or Mithi Kranti, the Sweet Revolution aims to encourage scientific methods of beekeeping and increase the production of good-quality honey and other bee products.

History

Beekeeping has been practiced in India since ancient times, when people collected honey from wild bees like the rock bee, little bee, and Indian hive bee. The Indian hive bee was domesticated but was kept in wooden logs or walls until the late 1800s. In 1909, Rev. Father Newton from South India developed a special beehive called the Newton Hive and set up beekeeping centers in Tamil Nadu. Between 1917 and 1938, beekeeping spread to regions like Travancore, Mysore, Kashmir, Punjab, and Uttar Pradesh. Today, Indian hive bees are mainly reared in Tamil Nadu, Kerala, Karnataka, Andhra Pradesh, Telangana, Odisha, and the North

Eastern states. A foreign bee species, the European honey bee (A. mellifera), was introduced successfully in Punjab in 1962 and is now reared in many states including Punjab, Haryana, Himachal Pradesh, Uttar Pradesh, Bihar, Rajasthan, and others. It has also recently been introduced in Andhra Pradesh, Telangana, and Tamil Nadu.

WORLD BEE DAY FOR PROMOTION OF BEEKEEPING

May 20 is celebrated as World Bee Day by the United Nations to spread awareness about bees, their importance in nature, and the threats they face. It is also the birthday of Anton Janša, a pioneer in beekeeping. The first World Bee Day was held on May 20, 2018, and the 2021 theme was "Bee Engaged: Build Back Better for Bees."

HONEY PRODUCTION IN INDIA

India's honey market was valued at Rs. 15,579 crore in 2018, growing at a rate of 10.9% per year between 2012 and 2018. Beekeeping provides jobs to around 3 lakh rural people. India currently has about 34 lakh bee colonies, though it has the potential to increase this to 200 million. The honey production rose from 81,300 to 1,05,000 tonnes, mainly due to an increase in bee colonies from 22 lakh to 34 lakh and honey exports increased from 29,600 to 51,500 tonnes, while domestic consumption stayed around 50,000 tonnes. As of 2019, there were 9,698 registered beekeepers managing over 15.5 lakh colonies. The top honey-producing states are Uttar Pradesh, West Bengal, Punjab, and Bihar, contributing over 50% of total production. Bharatpur in Rajasthan became a leading district, producing around 1,800 tonnes, mostly from mustard fields. In South India, about 25% of honey comes mainly from *A. cerana* bees. Over 75-85% of apiary honey is exported, and India exported 61,333.88 metric tonnes worth Rs. 632 crore (2017-18).

NATIONAL BEE KEEPING AND HONEY MISSION

The National Beekeeping and Honey Mission was announced by the Union Government as part of Atma Nirbhar Bharat package in 2020. The scheme is implemented by the National Bee Board and is approved for three years from 2020 to 2023.The scheme is aimed at the overall development and promotion of scientific beekeeping in India to achieve the objectives of the sweet revolution. The scheme is under the Ministry of Agriculture and Farmers Welfare ,GOI.

Case Study: Beekeeping Success in Thanjavur, Tamil Nadu

In 2021, a women's Self Help Group (SHG) in Thanjavur, Tamil Nadu started beekeeping under the Sweet Revolution with help from the National Bee Board and the state

horticulture department. They received 100 bee boxes, honey extractors, and a 40% subsidy. Within a year, they produced 4,000 kg of honey, earning about Rs. 4.8o lakhs, and gained extra income by selling beeswax and pollen. This not only improved their financial stability, but also supported crop yields through better pollination. Their success now inspires other rural groups across the state.

ECONOMICS OF BEE PRODUCTION

Beekeeping is a profitable business. Starting with 50 bee boxes costs around Rs. 3 lakhs, but the government offers up to 40% subsidy. An entrepreneur can earn around Rs. 2.4 lakhs per year by selling honey. Raw honey sells for Rs. 100–125 per kg, and each box gives about 50 kg of honey yearly.

Conclusion

India's per capita honey consumption is very low at just 20g per year, compared to 2.02 kg in New Zealand. Since honey and bee products are very healthy, they should be included in mid-day meals, sports nutrition, and defence diets. To boost honey production, we must grow bee-friendly crops like mustard, sunflower, pulses, and vegetables, and increase the number of bee hives. People should be made aware of other bee products like royal jelly, wax, and bee pollen. We also need to promote bee-safe farming practices to protect pollinators. Beekeeping must be treated as an important part of agriculture to improve crop yields and ensure food security—helping India achieve the Sweet Revolution.

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BUZZING WITH TRADITION: TRIBAL WISDOM IN TRADITIONAL HONEY MAKING

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Introduction

Traditional beekeeping, deeply ingrained in indigenous and rural communities worldwide, is an age-old practice that emphasizes low-cost, low-input techniques utilizing local resources. Unlike commercial beekeeping, its primary goals are subsistence, local trade, and the preservation of cultural heritage rather than large-scale production. In India, tribal communities share a unique, sacred relationship with bees, viewing them not just as a resource but as integral to their spiritual and environmental well-being. Their honey harvesting practices are holistic, prioritizing sustainable resource management and the welfare of bee colonies, incorporating rituals, deep ecological understanding, and profound respect for nature to maintain ecosystem balance.

Honey Bee Species in Tribal Beekeeping:

Species	Common name	Features
Apis dorsata	Rock bee	Wild, high honey yield, nests on cliffs/trees.
Apis cerana indica	Indian hive bee	Domesticated in wooden hives, moderate yield
Apis florea	Dwarf bee	Small nests in open places,low yield
Trigona spp.	Sting less bee	Common in south india,small yield,medicinal honey.

Traditional Management of Honey Bees:

Tribal communities demonstrate remarkable ingenuity and ecological knowledge in their bee management.

Hive Types: They utilize a diverse array of natural and locally available materials for hives:

i. Tree logs, bamboo hives, earthen pots, and wall niches are common, providing suitable, natural enclosures.
ii. Bark hives suspended from trees are unique to Northeast India, leveraging tree bark for elevated nesting.
iii. Hollowed wooden logs are used in regions like Bastar and Jharkhand, mimicking natural tree cavities.
iv. Bamboo pole bee hives are a peculiar and effective method developed by the Kani tribes for stingless bees. They split and rejoin large bamboo stems (30-35 cm diameter, 80-85 cm length) to create secure and manageable hives.
v. The Kunbis tribe innovatively uses clay pots, coconut shells, PVC pipes, and repurposed electric boxes, adapting hive volumes (0.7 L to 4.5 L) to different stingless bee nesting behaviours.









Colony Maintenance and Protection

Bee health is maintained by various strategies like

- Seasonal shifting of hives to follow nectar flows, optimizing honey production.
- Use of herbal smoke (e.g., neem, tulsi) to calm bees during harvesting, minimizing aggression.
- Strategic hive placement in shaded, undisturbed areas to protect colonies from extreme weather and disturbances.
- Application of herbal repellents to protect hives from pests like ants, avoiding chemical interventions.

Traditional Honey Extraction Methods

1. Smoke Method: Smoke disorients bees, making wild nest or hive approach safer.
2. Cut Comb Method: Only honey-filled comb sections are carefully cut, leaving brood intact to ensure colony survival and recovery.
3. Squeeze Method: Crushed honeycombs are manually squeezed through cloth or by hand to extract honey, a simple, non-mechanized approach.
4. KaniTribal Method: For their bamboo hives, Kani tribes open the pole, selectively remove honey storage pots, crush them in a white cloth, filter, and bottle, minimizing disturbance to the brood chamber.



Smoking method



Squeeze method



Cut comb method

Harvesting and Preservation

Honey is typically harvested during summer and post-monsoon periods, when floral abundance ensures mature honey with lower moisture content. Preservation involves storing honey in bamboo containers or earthen pots, sometimes mixed with medicinal herbs for enhanced properties and longer shelf life.

Uses of Honey in Tribal Regions

Honey in tribal communities transcends its role as food, holding deep nutritional, medicinal, cultural, and economic significance:

i. Nutritional: A vital natural sweetener and energy booster, crucial during labor or
ii. Medicinal: Essential in traditional healing, used for coughs, colds, fever, wounds, burns, skin infections, stomach ulcers, and sore throats due to its antimicrobial and anti-inflammatory properties. Often mixed with herbs for tonics.
iii. Childcare: Used to soothe teething babies or treat minor skin rashes.
iv. Skin and Hair Care: Applied as a natural moisturizer or conditioner.
v. Cultural/Ritualistic: Integral to rituals, religious offerings, marriages, and festivals, symbolizing purity and prosperity.
vi. Culinary: Added to traditional dishes, drinks, and fermented foods; used in meat preservation and to enhance tribal liquors.
vii. Economic: A crucial source of livelihood, sold locally or through cooperatives, supporting self-sustenance.
viii. Wellness: Believed by some communities to possess aphrodisiac properties and used in fertility treatments.

Common threads across Indian tribes' beekeeping practices include

Forest-based honey hunting, with a focus on sustainability. Exclusive use of natural, locally sourced materials for hives. Minimal interference with bee colonies, prioritizing their well-being. Intergenerational transmission of indigenous knowledge through oral tradition and practical training. Deep integration with local ecology, understanding flora, fauna, and bee behavior. Profound cultural and spiritual significance of beekeeping, extending beyond economic activity.

Traditional Beekeeping Methods Followed by Tribes of India:

TRIBES	LOCATION	EXTRACTION METHOD	HONEY BEE SPECIES	MANAGEMENT	USAGE
Paniya	Wayanad,Kerala	Log hives(mozhiyan)tied to	*Apis cerana indica*	Traditional hive management,seasonal	Medicinal use,Forest purpose

		trees			
Kurichiya	Wayanad ,Kerala	Sustainable tree hives	*Apis cerana*	Family based hive sharing,minimal inlet	Cultural rituals,consumption use
Kuruma	Wayanad, Kerala	Smoke driven extraction from forest hives	*Apis dorsata*	Forest based wild hive monitoring	Barter and medicine
Kandha	Rayagada,odisha	Smoke from sal leaves,Bamboo ladder	*Apis dorsata*	Climbing groups,seasonal harvesting	Local scale and ceremonies
Kattunayakan	Nilgiris,TN/ Kerala	Cliff hives with rope climbing	*Apis dorsata*	Nomadic,use of herbal smoke	Rituals and income
Irula	Tamilnadu	Smoke and herbal paste for calming bees	*Apis cerana*	Semi-domesticated methods	Medicinal and food use
Siddi	Uttara Kannada, Karnataka	Harvest from rocky cervices	*Apis florea*	Manual hive mapping	Consumed and sold locally
Sahariya	Sheopur,MP	Songs,ladders ,sal smoke	*Apis dorsata*	Community harvesting events	Food and healing purposes
Soliga	Biligirranga Hills, Karnataka	Cliff harvesting with vines	*Apis dorsata*	Forest department collaboration	Commercial and medical usages
Bhutia	Sikkim	Insulated high altitude hives	*Apis cerana indica*	Cold region techniques	Medicinal and cultural usage
Garasia	Rajasthan	Wall hives and plastered	*Apis florea*	Village level hive maintenance	Festival offerings
Toda	Nilgiris, TN	Buffalo dung smoke,fiber	*Apis dorsata*	Restricted to ceremonial	Ritual usage

		baskets		periods	
Bhil	Jhabua,MP	Wooden logs,bee songs	*Apis cerana*	Traditional tools, women - led	Trade and healing
Mishing	Majuli,Assam	Elevated bamboo hives	*Apis cerana*	Flood adaptive hives	Sale and kitchen usage
Dongria kondh	Niyamgiri, Odisha	Vertical cliff harvest	*Apis dorsata*	Spiritual protection of hives	Medicinal and rituals
Baiga	Mandla, Chattisgarh	Turmeric healing,Herbal smoke	*Apis dorsata*	Wild hive mapping	Community health
Karbi	Karbi Anglong,Assam	Hanging log hives	*Apis cerana*	Low smoke sustainable methods	Food and festivals
Santhal	Jharkhand	Tree based bee boxes	*Apis cerana*	Bee box training via NGOs	Income and barter
Gond	Chhattisgarh	Smoke and tree climbing	*Apis dorsata*	Community led hiving zones	Tribal trade
Juang	Keonjhar,Odisha	Natural rock hives	*Apis dorsata*	Herbal smoke,Basic gear	For healing and offerings

Success Stories

1. Pnar Community Tribes:

Residing in South Assam's Barak Valley, the Pnar, a Khasi subgroup, have an extraordinary connection to wild honey harvesting, supplementing their agriculture. Their legacy centers on the Ngap-lawe (Apis dorsata), yielding up to 50 kg per colony. They also domesticate Ngap-rapiang (Indian bee) (12-15 kg/hive/annum) and occasionally rear Ngaosnon (Western bee) (30-40 kg/hive/annum). During spring (March-May), 2-4 person teams use a daring "smoke and chase" technique with simple tools like the "Waip" (knife), "Khara" (bamboo basket), and "Jinkein" (single bamboo ladder). They navigate perilous

heights, using smoke to deter bees and skillfully cut honeycomb, always leaving a portion intact to ensure regeneration. This partnership with nature provides vital income (Rs. 300-400 per liter), showcasing how traditional knowledge and respect for nature lead to self-sufficiency and a sustainable future.



2. Kunbis Tribes

In Karnataka's Western Ghats, the Kunbis and four other ethnic communities have a profound success story in meliponiculture – keeping stingless bees, notably the Tetragonula iridipennis Smith "species complex." A study of 43 informants highlighted their rich understanding. The "Pannimookam" variety in Dakshina Kannada yields an impressive 650 ml three times a year. Beyond honey, products serve 20 specific uses across medicine (for flu, eye infections, even male infertility), crafts, food, and religious practices (bees symbolize luck, part of dowry). The Kunbis, in the Kali Tiger Forest Reserve, show the highest Relative Cultural Importance (RCI) index of 87.5 for bee products. Success lies in sustainable practices, adapting local materials like clay pots, coconut shells, and PVC pipes for hives (0.7 L to 4.5 L internal volume). They actively trap feral colonies and transfer wild bees to man-made hives. This blend of ancient wisdom and modern ingenuity safeguards both stingless bee populations and cultural heritage.

3. Kani Tribes

In Tamil Nadu's Western Ghats, the Kani tribal community uniquely rears the stingless bee, Trigona irredipensis (dammer bee), despite its usual non-domestication. This ancestral skill allows them to cultivate a highly medicinal honey, selling for Rs. 1000/Kg—20 times costlier than other honey. They use peculiar bamboo pole hives: 30-35 cm diameter, 80-85 cm length stems split and rejoined, with a narrow bee entry. After transferring the brood chamber, the colony settles. Hives are tied under hut roofs, bees smoothing the entrance with propolis and wax. A single colony yields 600-700g annually.



Honey is harvested by carefully removing and crushing only storage pots, filtered, and bottled, ensuring minimal brood disturbance. This method provides livelihood and conserves endangered stingless bees. The Kani believe this honey cures infections and is a weaning food, underscoring its traditional medicinal value.

Conclusion

The traditional beekeeping practices of India's tribal communities offer invaluable lessons in sustainable resource management, ecological harmony, and cultural preservation. Their age-old wisdom, passed down through generations, effectively addresses modern challenges, providing viable solutions for livelihoods and conservation. An innovative approach to integrating beekeeping within these communities should focus on culturally-sensitive training that merges local knowledge with modern techniques. This fosters sustainable practices, enhances livelihoods through honey and beeswax products, while simultaneously preserving biodiversity and strengthening community resilience. These success stories powerfully demonstrate the profound potential of traditional knowledge in shaping a sustainable future.

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FRUIT-FLY: AN ECONOMIC THREAT TO MANGO CULTIVATION

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Introduction

Mango (*Mangifera indica* L.) originated in the Indo- Burma region and has become naturalized and adapted throughout the tropics and subtropics. India has the richest collection of mango diversity with more than 1000 named varieties.Major mango producing countries are India, China, Thailand, Mexico, Pakistan, the Philippines, Indonesia, Brazil, Nigeria and Egypt. India ranks first and accounts for about 50% of the world's mango production with 2.5 million hectares producing annually 18.0 million tons. Insect pests are a major limiting factor in achieving full yield potential of mango varieties. About 400 species of insect pests are known to infest mango in different parts of the world. Commercial cultivation of mangoes, characterized by the area expansion, changing cropping patterns, varietal replacements and increased chemical interventions, has altered the pest complex and pest community structures significantly. In addition, climate change has induced the emergence of new pests or inadvertently encourages invasives. Scales, mealybugs, thrips, mites, leaf webber, stem borer, etc., earlier considered to be minor or secondary pests, have become serious problem in the recent past. Likewise, in mango fruit quality is largely affected due to the presence of fruit flies and affects the export value of the produce.

FRUIT FLY: OCCURRENCE AND DISTRIBUTION

Fruit flies are serious pests of mangoes in most parts of the world and cause eco- nomic losses. They are also the major constraint in the export of fresh mango fruits to foreign counties. There are several species of Tephritidae associated with mango across the globe. All *Dacus* species attacking mango have recently been placed under the genus *Bactrocera.* There are 325

species of fruit flies occurring in Indian subcontinent of which 205 are from India alone. Of them six to seven species are found infesting mango fruits in India. They include *Bactrocera dorsalis* (Hendel), *B. Zonata* (Bezzi), *B. correcta* (Bezzi) and *B. Caryeae* (Kapoor). Of them, *B. dorsalis*, commonly called the Oriental fruit fly, was earlier considered to be the most important and dominant species complex. It is reported from India, Sri Lanka, Myanmar, Nepal, Bhutan, Thailand, Vietnam and Cambodia in Asia. It is distributed throughout India; in the north it overwinters in pupal dormancy, but in the south, it is active throughout the year. *B. dorsalis* occurs on a wide range of fruit crops including guava, custard apple, banana, papaya, peaches and plums.



Fruitfly on mango



***Bactrocera dorsalis* – Adult**



Collection of fruitfly adults in methyl eugenol trap

BIOLOGY AND NATURE OF DAMAGE

Female fly punctures the skin of mature fruits with ovipositor and inserts white banana-shaped eggs (6–10/batch) in clusters into mesocarp. On hatching (after1–2 days), the maggots tunnel into the fruit and feed on the pulp. The larvae pupate in soil (5–10 cm) and flies start

emerging from April onwards with maximum population during May to July, which coincides with fruit maturity. The adults emerge after 10–12 days and may live for a few months. Affected fruits bear tiny ovipositional marks on the skin. Maggot feeding leads to rotting, and the pulp exhibits bad odour. Premature dropping is also noticed in orchards. All commercial varieties of mango are susceptible.

MANAGEMENT

1. Collect and destroy fallen fruits at regular intervals to minimize the further spread of infestation. Since pupation takes place in soil, deep ploughing during November–December exposes pupae to hot sun and predators.
2. Erect methyl eugenol bottle traps at 5 per acre throughout fruiting period, which attracts male flies. Protein Bait splashes on the trunk, and branches with 10% jaggery + Malathion(1 ml/l) attract female flies.
3. **Postharvest disinfestation of fruits:** Immerse mango fruits, within 24 h after harvest, in hot water at 48 °C ± 1 °C for 60 min. This process gives 100% mortaliity of eggs in the fruit without affecting the quality. For export to Europe or Japan, vapour heat treatment and to the USA, gamma irradiation (400 Gy) are mandatory.

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POTENTIAL OF CARBON CREDIT MARKET IN INDIAN AGROECOSYSTEMS: LEVERAGING SUSTAINABLE FARMING PRACTICES TO IMPROVE CARBON SEQUESTRATION

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Abstract

Agriculture plays a dual role in climate change by serving as both a source of greenhouse gas (GHG) emissions and a potential sink for carbon sequestration. Agriculture contributes substantially to GHG emissions due to practices such as the excessive use of synthetic fertilizers, methane emissions from paddy fields, livestock rearing, and the burning of crop residues. The emissions primarily of methane (CH_4), nitrous oxide (N_2O), and carbon dioxide (CO_2) accelerate global warming and climate change, thereby necessitating urgent mitigation strategies. One such strategy is the implementation of carbon credits in the agricultural sector. Carbon credits are marketable permits that allow the holder to emit one metric ton of CO_2 or its equivalent in other GHGs. In agriculture, carbon credits can be earned by adopting practices that either reduce emissions or sequester carbon in soil and biomass. According to the IPCC, carbon sequestration by forestry and agriculture alone significantly helps offset CO_2 emissions that contribute to global warming and climate change. Carbon sequestration in the agricultural sector refers to the ability of forests and farming areas to absorb carbon dioxide from the atmosphere. Agricultural practices such as no-tillage farming, crop rotation, cover cropping, organic matter application, and agroforestry improve soil health and enhance carbon storage. This paper aims to discuss the fundamental concepts and importance of carbon credits in Indian agriculture, highlighting agricultural practices that promote carbon sequestration and sustainable revenue for the farmers.

Keywords: GHG Emissions, Carbon Credit, Carbon Market, Carbon Auditing, Carbon Sequestration

1. Introduction

In India, agriculture is a vital sector, employing over half of the country's population and making a significant contribution to food security and rural livelihoods. However, it is increasingly vulnerable to the effects of climate change, such as unpredictable rainfall, rising temperatures, and frequent extreme weather events. At the same time, agriculture is also a significant contributor to GHG emissions, primarily through methane from paddy fields and livestock, nitrous oxide from excessive fertilizer use, and carbon dioxide from the combustion of fossil fuels and the burning of crop residues. These emissions accelerate global warming and climate change, which in turn impact crop yields, soil health, and farmer incomes.

To address these challenges, carbon credit systems in agriculture offer a promising solution. Farmers can earn carbon credits by adopting climate-friendly practices that sequester carbon in the soil or reduce emissions. These practices include no-tillage farming, crop rotation, cover cropping, organic matter application, and agroforestry. The concept of carbon trading, introduced under the Kyoto Protocol, enables countries and organizations with surplus emission reductions to sell credits to those that exceed their emission targets.

In India, this presents a unique opportunity for farmers to become active participants in the global carbon market. By registering their emission-reducing or carbon-sequestering practices under approved methodologies, farmers can generate carbon credits and sell them to industries or countries that need offsets. This system has the potential to provide an additional and sustainable source of income, particularly for small and marginal farmers, thereby aligning climate action with rural economic development. To support this system, carbon auditing plays a crucial role by measuring, monitoring, and verifying the carbon reductions, making farmers eligible to trade verified credits in carbon markets. These verified credits can then be sold, offering farmers an additional source of income while supporting climate change mitigation.

This mechanism creates a win-win scenario for Indian farmers by encouraging sustainable farming practices that reduce greenhouse gas emissions and improve soil health, while also providing them with an additional source of income through the sale of carbon credits. Especially for small and marginal farmers, carbon trading can enhance economic resilience while supporting national and global climate goals. Thus, integrating carbon credit mechanisms into Indian agriculture can drive sustainable farming practices, reduce greenhouse gas emissions, and

create new income opportunities for farmers, contributing to climate resilience and rural development.

2. Functionalising Carbon Credit in agriculture:

The concept of carbon credits has gained increasing relevance in Indian agriculture, particularly in light of global climate agreements such as the Kyoto Protocol and the Paris Agreement, which emphasize the urgent need to reduce GHG emissions. Under international frameworks, countries and companies that exceed their emission limits must either reduce emissions or purchase carbon credits. The United Nations allocates a specific quantity/number of credits to each country, which are then monitored, issued, and reported annually by national governments. Carbon credits are permits that allow the owner to emit a certain amount of carbon dioxide or other greenhouse gases (GHGs). One credit allows the emission of one ton of carbon dioxide or the equivalent of other greenhouse gases.

The primary aim of the carbon credit system is to reduce overall GHG emissions. In agriculture, these credits provide farmers an opportunity to earn additional income by adopting sustainable practices that sequester carbon or reduce emissions. These credits represent the reduction or removal of one metric ton of CO_2 or equivalent from the agricultural land. They can be sold on the voluntary carbon market, where companies purchase them to offset their emissions to meet sustainability goals.

3. Potential in Agroecosystems:

Indian farmers can generate surplus carbon credits by implementing carbon-sequestering techniques such as organic farming, conservation agriculture, and agroforestry. These carbon credits can subsequently be sold to entities looking to offset their emissions, thereby creating a new source of revenue for farming communities. This presents a unique opportunity to monetize sustainable practices by converting sequestered carbon into tradable credits, which are only valid if they represent actual removals, not merely reductions. This mechanism aligns with global efforts to combat climate change while promoting sustainable development in rural communities. Indian agriculture can enhance its participation in voluntary carbon markets by leveraging carbon auditing and climate-smart technologies. With rising pressure on industries to achieve net-zero targets, carbon credit trading has emerged as a practical approach to connect environmental sustainability with rural economic growth. Thus, carbon credits hold the potential to transform Indian agriculture into a climate-smart sector that not only conserves the environment but also

ensures long-term financial security for farmers. Figure 1 illustrates the potential for CO2 sequestration and the trading of carbon credits as a means of complementing offsets.

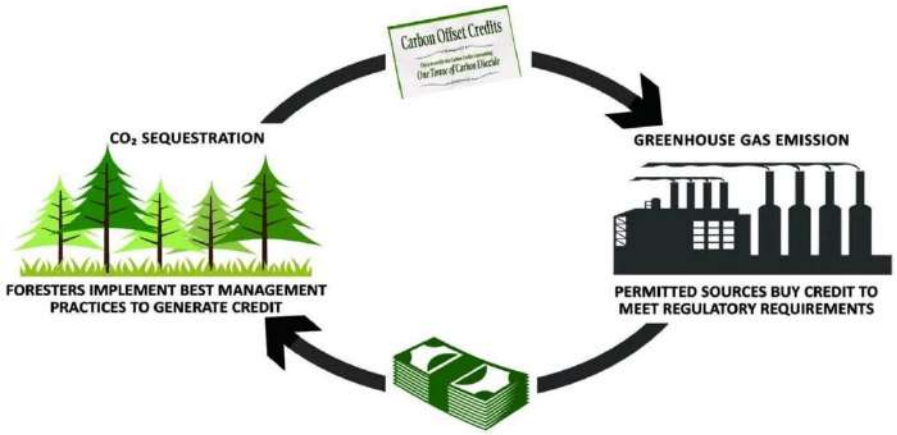


Figure 1. Carbon Credit Trading

4. Carbon Auditing/Accounting:

Carbon auditing is a scientific method used to assess and quantify total GHG emissions and carbon sequestration from specific activities, particularly in agriculture. It includes direct emissions from farm operations (e.g., fuel use and fertilizer application) and indirect emissions (e.g., manufacturing of inputs). Through standardized methodologies, such as the IPCC guidelines or ISO standards, carbon auditing helps identify emission hotspots and opportunities for mitigation.

According to the 1996 IPCC guidelines, the total carbon credits in a given land-use system were estimated by converting the stored biomass and soil organic carbon (SOC) into CO_2 equivalents. To perform this conversion, a molecular ratio of 3.67 was used, representing the stoichiometric relationship between elemental carbon and carbon dioxide. This factor reflects the molecular weight difference, allowing for an accurate representation of carbon storage and sequestration in terms of CO_2 emissions control. In agriculture, carbon auditing enables farmers and policymakers to assess the effectiveness of farming practices that impact carbon storage in soil and biomass. The quantified emission reductions or carbon sequestration are then documented and certified by third-party verifiers. Once verified, these emission savings can be converted into carbon credits, each representing one metric ton of CO_2 equivalent that has been avoided or sequestered.

5. Carbon Market:

Carbon markets enable the trading of carbon credits, which can be sold in either compliance or voluntary markets, creating an opportunity for farmers and industries to generate additional income. Compliance and voluntary carbon markets are both mechanisms for trading carbon credits, but they differ significantly in their regulatory structure and purpose (Figure 2). Compliance carbon markets are regulatory in nature and operate under government-mandated frameworks such as cap-and-trade systems. Entities in these markets are required to reduce emissions and can trade credits to meet their targets. Voluntary carbon markets, on the other hand, are non-regulatory and allow companies or individuals to purchase credits to voluntarily offset their emissions and support climate mitigation projects.

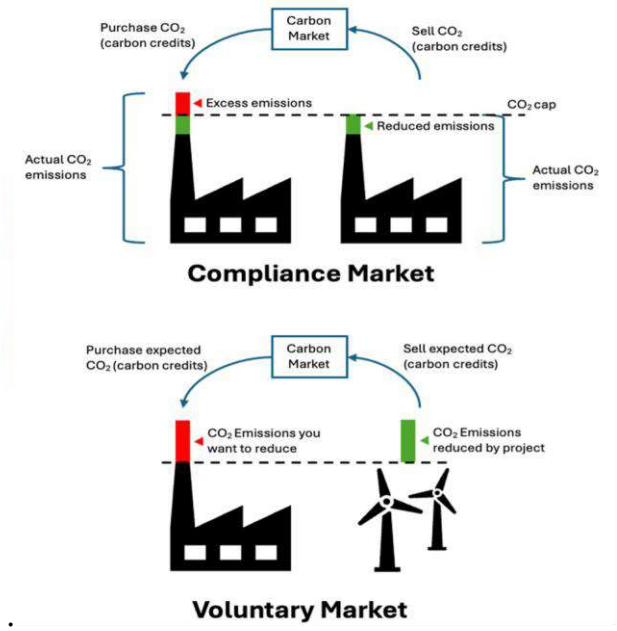


Figure 2. Types of Carbon Markets

In India, industries have gained substantial experience with both market types. Under compliance markets, schemes such as Perform, Achieve and Trade (PAT) and Renewable Energy Certificates (RECs) have driven emission reductions. Voluntary mechanisms, like the Clean Development Mechanism (CDM), have also been actively adopted. India holds the second-largest number of registered CDM projects globally. From 2015 to June 2024, Indian units under the PAT scheme alone have collectively saved over 106 million tonnes of CO_2 emissions. Thus, these market approaches provide incentives through tradable credits or certificates, reflecting India's readiness and capacity to scale a comprehensive carbon market.

6. Carbon Sequestration in Agriculture:

Carbon sequestration refers to the process of capturing atmospheric carbon dioxide (CO_2) and storing it securely in natural sinks, such as soil, vegetation, and geological formations. In the agricultural sector, this process primarily occurs through photosynthesis, where plants absorb CO_2 and store it as biomass in their roots, stems, leaves, and ultimately within the soil. Agricultural soils, being the most significant terrestrial carbon sink, play a crucial role in long-term carbon storage. Several factors, including soil type, crop species, climate conditions, and land management practices, influence the effectiveness of sequestration in farmlands.

Sustainable agricultural techniques, such as conservation tillage, crop rotation, agroforestry, cover cropping, and organic manure application, enhance soil organic carbon (SOC) levels, improve soil structure, and reduce carbon losses due to decomposition and erosion. Forests and grasslands also play a significant role in long-term carbon storage due to their dense root systems and stable vegetation cover. By adopting sustainable farming techniques, agricultural lands can become powerful tools for mitigating climate change, reversing soil degradation, and contributing to global efforts to lower net carbon emissions.

7. Agricultural Techniques to Enhance Carbon Sequestration:

Several agricultural practices and technologies play a crucial role in reducing GHG emissions and mitigating climate change. Figure 3 illustrates the methods that enhance soil carbon sequestration, preserve existing soil carbon, and help curb the release of carbon dioxide, methane, and nitrous oxide into the atmosphere.

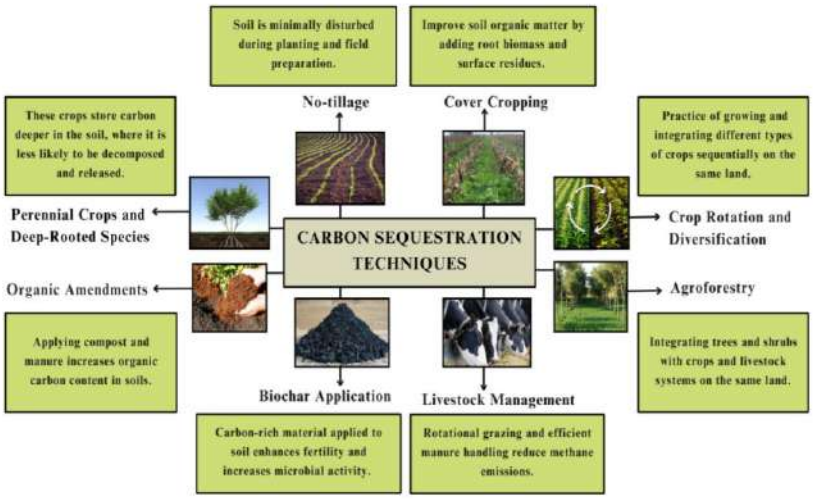


Figure 3. Agricultural practices to enhance Carbon Sequestration and lower GHGs

7.1. Conservation tillage or no-tillage:

Conservation tillage, also known as no-tillage, is a farming method where the soil is minimally disturbed during planting and field preparation. By reducing the frequency and depth of soil turning, this method helps maintain soil integrity, prevents erosion, preserves moisture, and enhances the soil's ability to store carbon, thereby reducing GHG emissions.

7.2. Cover Cropping:

Cover crops improve soil organic matter by adding root biomass and surface residues. This biomass contributes to long-term carbon sequestration in the soil while also reducing the need for synthetic fertilizers, indirectly lowering CO_2 emissions from their production and application.

7.3. Crop Rotation and Diversification:

Crop rotation is the practice of growing different types of crops sequentially on the same land, while diversification involves integrating multiple crops in a single season or farming system. These strategies enhance soil fertility, disrupt pest cycles, and increase the diversity of organic inputs to the soil.

7.4. Agroforestry:

Agroforestry integrates trees and shrubs with crops and livestock systems on the same land. Trees act as long-term carbon sinks by absorbing atmospheric CO_2 and storing it in biomass and soil. Their deep root systems contribute to long-term soil carbon storage and help mitigate climate change by absorbing atmospheric CO_2 through the process of photosynthesis.

7.5. Improved Livestock Management:

Practices such as rotational grazing and efficient manure management reduce methane emissions and enhance grassland productivity. Healthy pastures store more carbon in the soil, contributing to both soil carbon sequestration and lower greenhouse gas emissions from livestock.

7.6. Biochar Application:

Biochar is a carbon-rich, stable material produced by heating organic biomass in the absence of oxygen (pyrolysis). When applied to soil, biochar enhances soil fertility, improves water retention, and increases microbial activity. Its stability ensures that the carbon is stored in the soil for hundreds to thousands of years, effectively removing CO_2 from the atmosphere.

7.7. Organic Amendments (Compost and Manure):

Applying compost and manure increases the organic carbon content in soils, enhancing their ability to act as carbon sinks.

These organic inputs reduce reliance on synthetic fertilizers, thereby lowering CO_2 emissions associated with their production and use.

7.8. Nitrogen Use Efficiency:

Improving nitrogen use through precision farming, cover cropping, organic manure, nitrogen-fixing rotations, composting, and integrated pest management reduces nitrous oxide emissions while enhancing soil fertility and overall farm sustainability.

7.9. Methane Capture:

Livestock waste, especially from dairies, emits methane and nitrous oxide. Systems like anaerobic digesters capture methane for energy use, reducing emissions, odors, and manure handling costs while supporting on-farm power generation and sustainable waste management.

7.10. Perennial Crops and Deep-Rooted Species:

Perennial and deep-rooted crops store carbon deeper in the soil, where it is less likely to be decomposed and released. Their continuous cover also minimizes carbon loss and enhances the ecosystem's overall capacity to absorb CO_2.

7.11. Irrigation and Water Management:

Upgrading irrigation methods, such as using drip systems, improving mechanical components, and reducing operational hours, can significantly decrease water usage and the application of nitrogen-based fertilizers. These improvements not only reduce nitrous oxide emissions, a potent greenhouse gas, but also decrease water withdrawals, making agricultural practices more sustainable and climate-resilient.

7.12. Renewable Energy:

Renewable energy sources, such as wind and solar, offer valuable opportunities for the agricultural sector to reduce greenhouse gas emissions. By integrating these clean energy technologies into farm operations, such as for powering irrigation systems, machinery, or storage facilities, farmers can reduce reliance on fossil fuels.

7.13. Precision Agriculture and Digital Tools:

Technologies such as GPS, sensors, and AI optimize input use and improve crop efficiency, resulting in healthier plants that absorb more CO_2 through photosynthesis. These tools help reduce soil disturbance and input overuse, contributing to lower overall CO_2 emissions and increased carbon retention in soils.

Conclusion

In conclusion, carbon credit systems in Indian agriculture closely align with several of the United Nations' Sustainable Development Goals (SDGs). It aligns with goals 1, 2, 8, 9, 12, 13, 15, and 17, specifically SDG 1 and 8, which aim to eradicate poverty and create green employment opportunities, respectively. Carbon-sequestering techniques, including conservation agriculture, organic farming, and agroforestry, enhance soil health and productivity. Thus, supporting SDG 2: Zero Hunger by increasing agricultural resilience and food security. Reducing greenhouse gas emissions, such as carbon dioxide, methane, and nitrous oxide, through climate-smart practices directly advances SDG 13: Climate Action. Meanwhile, efficient resource use and reduced dependence on synthetic inputs align with SDG 12: Responsible Consumption and Production. By improving soil carbon, promoting agro-biodiversity, and minimizing land degradation, these practices cope with SDG 15: Life on Land, ensuring long-term ecosystem sustainability. Furthermore, the adoption of carbon auditing and MRV systems also aligns with SDG 9: Industry, Innovation and Infrastructure, and participation in carbon markets fosters collaboration under SDG 17: Partnerships for the Goals. Thus, carbon credits not only offer a climate mitigation tool but also represent a multi-dimensional strategy to enhance the sustainability, equity, and economic viability of Indian agriculture in alignment with global development goals. Hence, carbon credit systems offer a promising future thrust for Indian agriculture, linking environmental stewardship with economic opportunity, and paving the way for a more resilient, climate-smart, and financially secure farming sector.

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INTEGRATED WEED MANAGEMENT FOR PADDY CULTIVATION

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Introduction

Weeds played a major role in productivity enhancement of different crops. In India it is estimated that 33 percent yield loss occurred due to weeds, whereas insects and diseases are responsible for 26% and 20%, respectively. Weeds interfere with crops by competing for light, water, nutrients and space resulting in reduction of crop yield and quality. The yield reduction in any crop through weed competition depends on several factors such as weed flora and density, duration of competition, management practices and climatic conditions. In the agro ecosystems ideal environmental conditions provided for optimal crop productivity are being exploited by the associated weeds. Therefore, timely weed management is crucial for attaining optimal grain yield of a crop. However, none of the single weed control methods are effective for all weeds and to manage weeds effectively and sustainably in the long run, it is essential to develop and deploy flexible integrated weed management (IWM) practices. IWM consists of physical, cultural, chemical, and biological management.

Weeds are undoubtedly a major biotic constraints to rice production in most rice growing areas in the world. The problem associated with weeds in rice are aggravated dramatically due to changes in conventional rice cultivation to different method of cultivations like wet and dry seeded rice cultivation, direct seeded rice with limited water in response to declining availability of water and labour. Weeds are responsible for heavy rice yield losses, to the extent of complete crop loss under extreme conditions. Because of the diversity and plasticity of weed communities, weed management needs to be viewed as a continuous process. Weeds not only cause huge reductions in crop yields but also increase cost of cultivation, reduce input efficiency, interfere

with agricultural operations, impair quality, act as alternate hosts for several insect-pests, diseases, affect aesthetic look of the ecosystem, native biodiversity, as well as affect human and cattle health. Weeds are known to account for nearly one third of the losses due to various biotic stresses.

Integrated Weed Management offers most practical and cost effective means of reducing weed competitions. IWM is a science-based decision-making process that coordinates the use of environmental information, weed biology and ecology, and all available technologies to control weeds by the most economical means, while posing the least possible risk to people and the environment. Many advances have been made in recent years in India on IWM and these strategies are needed for the successful management of ever-increasing problem of weeds in rice.

MAJOR WEED FLORA IN RICE FIELD

Grasses are the most important competitive weed species in rice field, it grows simultaneously along with rice in the early stages depending upon the soil moisture and prevailing weather conditions. Some of the important grass weeds observed in the rice fields are, jungle rice, barn yard grass, crow foot grass, para grass, large crab grass, Bermuda grass, etc.

Sedges are noticed in the mid vegetative stages of the rice crop especially in the tillering stages. Purple nut sedge, small flower umbrella sedge, rice flat sedge are commonly prevails in the rice field.

Considerable population of broad leaved weeds also observed in the paddy fields. Depending upon the climate and moisture conditions the broad leaved weeds are emerged whereas compared to grasses and sedges, the yield loss will be lesser in broad leaved weeds affected field. Sessile joy weed, alligator weed, goat weed, black pig weed, four leaf clover, Indian mustard, water spinach are weeds occurred in the rice fields.

CROP WEED COMPETITION

- The critical period of weed competition is the shortest time span during the crop growth when weeding results in highest economic returns.
- The crop yield level obtained by weeding during this period is almost similar to that obtained by the full seasons weed free conditions.
- The critical period of weed competition is approximately 1/3rd duration of the crop.

Integrated Weed Management

A holistic integrated approach is required to eradicate and control the weeds over the period of

time. Integrated weed management involves the concept of multiple tactics of weed management, maintenance of weed population below economic injury level and conservation of environment quality. A successful IWM strategy has the principles of enhancing farmer's profitability, environmental protection and responsiveness to consumer preference.

Preventive methods

- Use of weed free seeds.
- Use of weed free seed bed.
- Use clean tools and machinery.
- Clean irrigation canals and bunds
- Prevent entry of water-carried vegetative propagules of weeds that are perennial.

Eradication Methods

Eradication can be done by

- Destroying the species at the initial stage of introduction.
- Degenerating the buried dormant but viable seeds by flooding

Cultural Methods

- Preparatory cultivation - Incorporates weeds into soil, often to a depth of 10 to 15 cm to destroy the existing weed growth.
- Flooding and intensive puddling is an added advantage in lowland rice weed management.
- Cultural practices like dual cropping of rice-azolla and rice-green manure reduces the weed infestation to a greater extent.
- Summer ploughing and cultivation of irrigated dry crops during post-rainy periods reduces the weed infestation.
- Planting method - transplanting is primarily done for good weed control.
- Select cultivars which are having greater seedling vigor, leaf area development, early height growth rates and tillering ability.

Manual Weed Control

- Weeds are removed and collected from crop fields by hand. The collected weeds are piled on bunds or in case of certain weeds, taken home to feed animals.

- Manual weeding is the most widely used method of weed control in rice which is, however, difficult, time consuming and often costly.

Transplanted Rice

- Take up one or two hand weeding between 15-40 days after transplanting

SRI

- Manual hand weeding to remove left out weeds after cono weeding

Rainfed Rice

- First weeding can be done between 15 and 21 days after germination.
- Second weeding may be done 30 - 45 days after first weeding

Mechanical Weed Control

Mechanical control consists of methods that kill or suppress weeds through physical disruption. Such methods include pulling, digging, disking, ploughing and mowing.

Transplanted Rice

- Use of rotary weeder four times from 15 DAT at 10 days interval.
- It saves labour for weeding, aerates the soil and root zone, prolongs the root activity, and improves the grain filling though efficient translocation and ultimately the grain yield.

Upland Dry Seeded Rice

- Repeated inter-cultivation by passing hoe or small blade harrow 2-3 times between 20-45 days after sowing.

Biological Weed Control

- Use of living organisms' viz., insects, disease organisms, herbivorous fish, snails or even competitive plants for the control of weeds is called biological control.
- In biological control method, it is not possible to eradicate weeds but weed population can be reduced.
- *Hirschmanniella spinicaudata* is a rice root nematode which controls most upland rice weed.
- *Bactra verutana* - a moth destroys *Cyperus rotundus*.
- *Ludiwigia parviflora* is completely destroyed by *Altica cynanea* (steel blue beetle)

Chemical Weed Control

Using chemicals, generally referred as herbicides, for the control of weeds is called chemical

weed control. Herbicide application can provide the most effective and time-efficient method of managing weeds.

Transplanted rice

Pre-emergence herbicides

- Use Butachlor 1.25 kg/ha or Anilophos 0.4 kg/ha, Thiobencarb 50 % EC @ 2 kg/ha (1 kg ai/ha), pendimethalin 30 % EC @ 4.5 kg/ha (1.5 kg ai /ha), as pre-emergence application. Alternatively, pre-emergence application of herbicide mixture viz., Butachlor 0.6 kg + 2, 4 DEE 0.75 kg/ha, or Anilophos + 2,4 DEE 'ready-mix' at 0.4 kg/ha followed by one hand weeding on 30-35 DAT will have a broad spectrum of weed control.
- Any herbicide has to be mixed with 50 kg dry sand on the day of application (3-4 DAT) and applied uniformly in the field with thin film water on the 3rd DAT. Water should not be drained for next 2 days from the field (or) fresh irrigation should not be given

Post – emergence herbicides

Where broad-leaved weeds and sedges are predominant, apply 2,4-D sodium salt (Fernoxone 80% WP) 1.25 kg/ha dissolved in 625 litres of water with a high volume sprayer, three weeks after transplanting or when the weeds are in 3-4 leaf stage.

Wet Seeded Rice

- Butachlor 50% EC @ 2.5 kg/ha (1.25 kg ai/ha) or Thiobencarb 50% EC @ 2 kg/ha (1.00 kg ai/ha) 6-9 days after sowing
- Pretilachlor + safener (sofit) 50% EC@ 2.25 kg/ha (0.45 kg ai/ha) 3-5 days after sowing. Give a follow up application of 2,4-D 3.8% EC @ 3.04 kg/ha (0.8 kg ai/ha) at 20 days after sowing.
- To control *Echinochloa sp*. spray cyhalofop butyl 10% EW @ 0.8 kg/ha (0.08 kg ai/ha) at 15-18 days after sowing.

Dry Seeded Rice

Spray any of the following pre-emergent herbicides:

Thiobencarb 50% EC @ 3 kg/ha (1.5 kg ai/ha), butachlor 50 % EC @ 2.5 kg/ha (1.25 kg ai/ha), oxyfluorfen 4% EC @ 6 kg/ha (0.15 kg ai/ha), pendimethalin 30% EC @ 4.5 kg/ha (1.50 kg ai/ha), pretilachlor 50% EC @ 3.75 kg/ha (0.75 kg ai/ha) on the same day of seeding or within six days of seeding.

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MORPHOLOGY AND PHYSIOLOGY OF SILK GLAND IN SILKWORM

Article ID: AG-VO5-I07-39

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Introduction

Silk is a fine continuous protein fiber secreted by various insect larvae for making protective shell/cocoons. The silk which is commercially produced all over the world in large scale is mulberry silk which is synthesized by mulberry silkworm larva, ***Bombyx mori***. The silk gland is the only organ where silk proteins are synthesized in *Bombyx mori*. This paper highlights the structure and function of silk gland in silkworm.

Origin of silk gland in silkworms

Silk gland is ectodermal in origin that evolved several times in the phylogeny from the pair of larval labial salivary glands. The silk glands lie ventral to the alimentary canal. Silk gland's morphogenesis gets completed in the embryo within 24 – 48 hours before hatching. During larval life they increase their secretory potential by growing in size and ploidy. Their function fluctuates in each instar according to a larval pattern which is characterized by the initiation of intensive RNA transcription with the resumption of feeding by the higher rate of protein synthesis during feeding and by the cessation of these activities with the advancement of the next moult. In the last larval instar, the silk glands develop according to a metamorphic pattern with enhanced function that differs from the larval one and especially by the programming of silk glands for histolysis. Silk proteins are stored in the lumen of the silk gland for around eight days during the fifth instar. In fully matured larva, silk gland occupies most of the body cavity and weighs approximately 1.51 g.

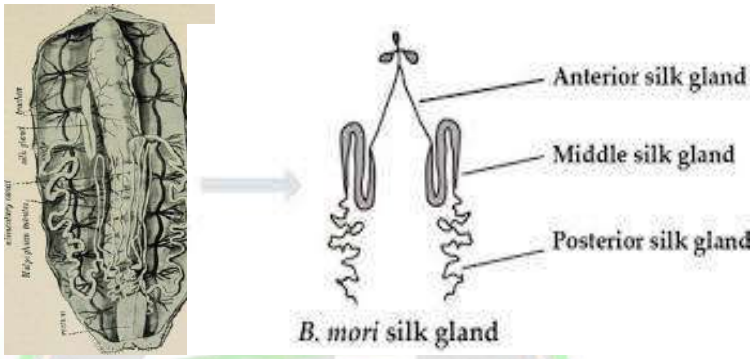
Regions of silk gland

The silk gland of *Bombyx Mori* is a tubular epithelium which is divided into three regions with different diameters in different regions and has a precise cell-to-cell boundary with fixed number of cells.

- ✓ **Posterior silk gland** - contains folds that secrete fibroin proteins
- ✓ **Middle silk gland** - stores and matures the fibroin and secrete sericin
- ✓ **Anterior silk gland** - guides the silk fibres through the spinneret opening



***Bombyx mori* larva**



***Bombyx mori* larva- Dissection view**

Cross section of silk gland

Histologically the entire silk gland has 3 layers



1. Tunica propia

It is the outer layer having uniform thickness over the entire silk gland

2. Glandular layer

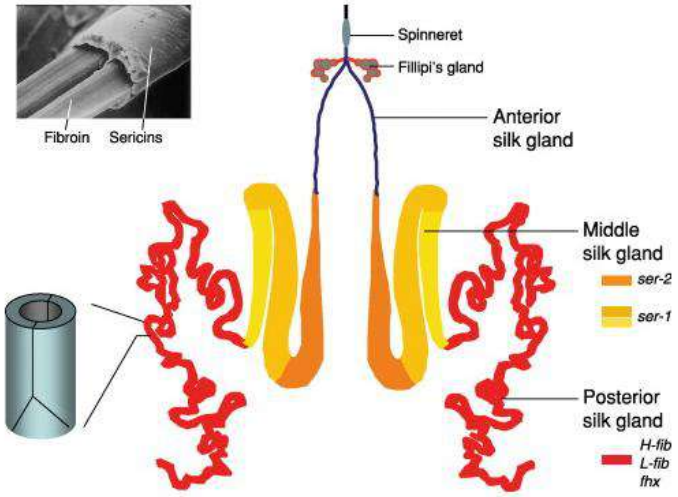
It is the middle layer and has gland cells which increase in size during later instars of larval development. The number of gland cells varies with races. European races have maximum number of gland cells than Japanese univoltine followed by Japanese bivoltine, Chinese bivoltine and Chinese multivoltine races. In young worms, gland cell nucleus is round in shape and matured larva has characteristic branched nuclei in the gland cells.

3. Tunica intima

It is the innermost layer and has varying thickness in different regions of silk gland. In anterior region of gland, this layer is very thick and shed at each moult whereas in other regions of silk gland, it is thin and not shed during moulting period.

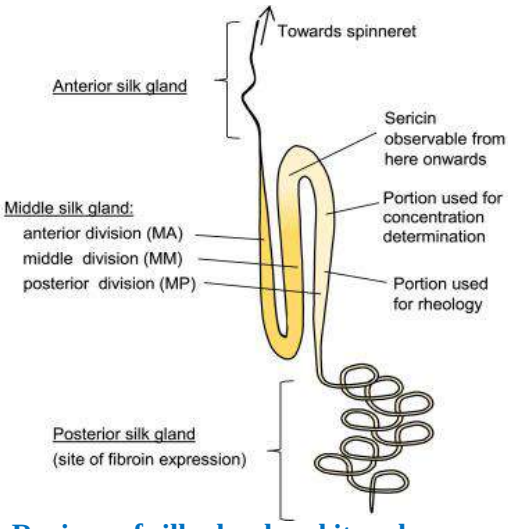
Functioning of silk gland

The posterior silk gland (PSG) and the middle silk gland (MSG) are secretory territories specialized for the massive production of the silk proteins. The three fibroin subunits, encoded by the heavy fibroin chain (*h-fib*), light fibroin (*l-fib)*, and fibrohexamerin (*fhx*) genes are synthesized in the PSG cells whereas the sericin encoded by the genes *ser-1* and *ser-2* are synthesized in the MSG cells. Paired secretory parts (Fillipi's gland) are linked to the anterior silk gland which then connected to the labial spinneret through which silk filament will be ejected.



Structure of Silk Gland

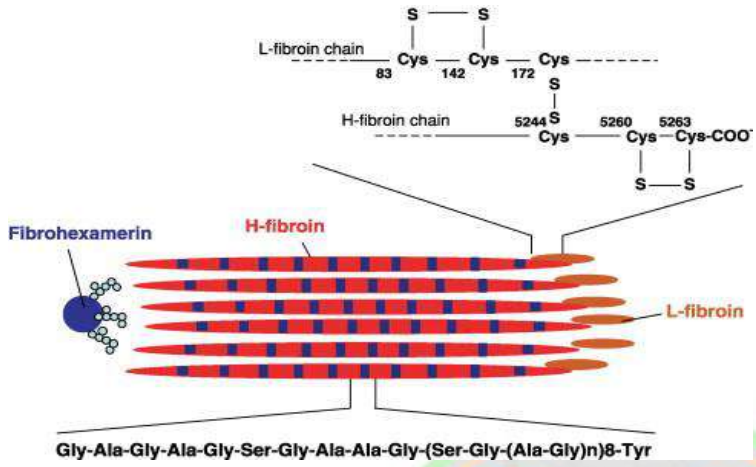
Posterior Silk Gland (PSG) and Fibroin Production



Regions of silk gland and its role

Posterior Silk Gland is the blunt, highly folded tubular region present in the midst of the derma-visceral muscles and attached to the tracheal bushes of silkworm. It produces fibroin, a matter of insoluble core in the silk thread. It is secreted as a precursor fibrinogen which on extrusion from the gland gets denatured to fibroin. This complex protein is composed of three subunits, the heavy (H-fibroin) and the light fibroin chain (L-fibroin) which are linked through disulphide bonds, and

fibrohexamerin (previously designated as P25), which is associated with the H-fibroin/L-fibroin dimer through non-covalent bonds. The stoichiometry relationship accommodates a 6:6:1 relative ratio of the three subunits as shown in the figure below.



Stoichiometric relationship of fibroin



Posterior silk Gland

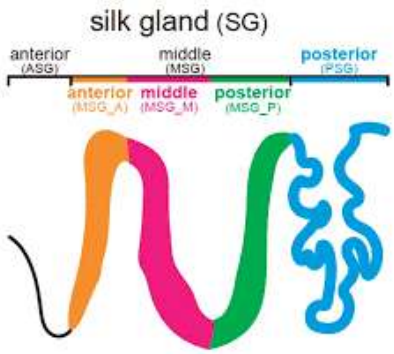
Middle Silk Gland (MSG) and Sericin Production

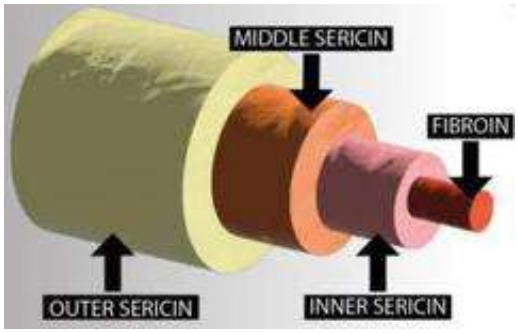
The middle silk gland produces sericin fraction of the silk filament which is composed of peptides and is characterized by their solubility in hot and alkaline water, a property that enables the industrial degumming of silk. Sericin has unusual composition which represents about one-third of all amino acids. Their diversity arises from frequent allelic polymorphisms of the two single-copy genes, *ser-1* and *ser-2* and from the differential splicing of their respective precursor mRNA. MSG also acts as the storage reservoir of fibroin where fibroin gets mature during the storage period. Sericin serves to glue the silk threads together.

Regions of Middle Silk Gland

It is the most prominent and widest part of silk gland. It remains folded in a W-shape and thus has 3 limbs in it which are posterior, middle and anterior limbs.

- **Posterior limb** secretes sericin-I (inner sericin)
- **Middle limb** secretes sericin II (middle sericin) which then surround the sericin-I secreted from the posterior arm
- **Anterior limb** secretes sericin III (outer sericin) which then surround the sericin II secreted in middle limb

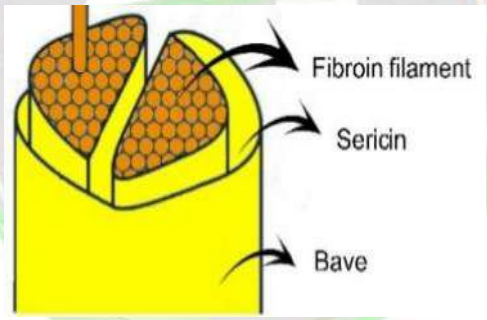




Arrangement of proteins in silk filament

Anterior Silk Gland

Anterior silk gland has a uniform thickness and is very thin. There is no secretory role for the anterior region of silk gland. It role is to transport assembled silk fibre to the spinneret. The anterior region of two sides opens at the base of the spinneret, a median projection in the labium. The two filaments coming out of two sides are called brins and the sericin layer of two brins bind together into a single filament or a bave.



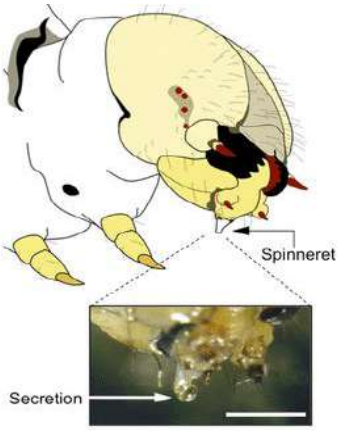
Structure of Silk filament

Filippi's gland

In the head region of larva, a pair of gland is situated which opens into the anterior silk gland near its opening at the spinneret. It is assumed that, these gland secrete some waxy materials to lubricate the passage of silk while coming out. Filippi's gland is also called as lyonnet's gland.

Spinneret

Spinneret is the tubular or conical projection at the median part of labium. The secreted silk comes out as a filament or thread as it passes through the silk press which resembles a typical salivary pump. Spinneret draws out the silk in liquid form at the tip which then exposed to air and gets dried as silk thread.



Spinneret in silkworm

Conclusion

This silk gland alone makes a new branch in the field of life science. Silk gland is very simply organized as a one-cell layered glandular epithelium that has a great importance in the field of sericulture as it synthesizes the culturally valuable silk and pharmaceutically important proteins.

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Volume: 05 Issue No: 07

OFFSHORE AQUACULTURE: AN EMERGING FRONTIER IN SUSTAINABLE SEAFOOD PRODUCTION

Article ID: AG-V05-I07-40

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Abstract

Offshore aquaculture, or open ocean aquaculture, is an emerging approach to seafood production that relocates fish and shellfish farming into deeper, high-energy marine environments away from the coast. This strategy aims to reduce environmental impacts common in inshore systems, such as nutrient accumulation and benthic degradation, by leveraging stronger ocean currents for waste dispersion. Technological advances—particularly in submersible cage design, automated feeding, and remote monitoring—have made offshore farming increasingly feasible. However, concerns remain regarding ecological sustainability, disease transmission, fish escapes, and the dependence on wild fish for feed. Regulatory challenges and high operational costs also constrain development. Despite these uncertainties, offshore aquaculture holds significant promise to expand global seafood supplies sustainably if supported by rigorous research, innovative engineering, and effective governance frameworks.

Introduction to Offshore Aquaculture

Offshore aquaculture, also referred to as open water or open ocean aquaculture, represents a rapidly developing approach to mariculture in which fish farms are established in deeper, less sheltered marine environments some distance from the coast. Unlike traditional inshore aquaculture, which relies on calm, shallow waters, offshore systems expose cultured fish stocks to more dynamic and naturalistic living conditions, including stronger ocean currents and enhanced nutrient flows. Although early initiatives in this field often occurred in merely exposed coastal areas rather than fully offshore locations, significant technological and operational advancements have begun to unlock the potential of deeper water sites for commercial

aquaculture production. Maritime classification societies such as DNV GL have noted that knowledge building is still needed across engineering, biology, and environmental management to safely and efficiently realize these offshore opportunities.



Figure 1:Offshore aquaculture(Source:Wikipedia)

Environmental Motivation for Offshore Systems

One of the primary motivations for moving aquaculture further offshore is the desire to mitigate environmental impacts associated with traditional inshore farming. Inshore aquaculture operations are commonly criticized for allowing uneaten feed and fish feces to accumulate on the seafloor, causing eutrophication, benthic degradation, and sometimes promoting harmful algal blooms. Proponents argue that by relocating farms into deeper, higher-energy environments, nutrient wastes can be more readily diluted and dispersed by ocean currents, thereby reducing localized pollution. Furthermore, the spatial expansion offshore opens opportunities for scaling up production to satisfy rising global seafood demands without overwhelming fragile nearshore ecosystems. Offshore facilities also benefit from fewer conflicts with coastal marine resource users, though competing claims for offshore space still arise.

Technological Development and Infrastructure

The transition to offshore aquaculture requires robust technological solutions capable of withstanding harsh marine conditions. The engineering challenges include designing cages that can tolerate storm events, heavy swells, and strong currents while preventing fish escapes and predator intrusions. Submersible cages, often fabricated from high-strength materials such as Spectra polyethylene fibers, have emerged as a favored technology. These structures can be submerged to minimize wave action and surface interference, while being anchored securely to the seafloor. Modern offshore farms frequently integrate automated feeding buoys, sensor networks, and telemetry systems for remote monitoring and control. This technological

sophistication contributes to high capital costs but also increases operational reliability and biosecurity. Offshore cage designs continue to evolve, aiming to reduce maintenance requirements and further lower production costs.

Ecological Impacts and Uncertainties

Although offshore aquaculture promises a reduction in benthic pollution compared to inshore systems, its ecological impacts remain incompletely understood. While nutrient dilution offshore may mitigate some localized effects, dissolved and particulate wastes are still released into the environment, and large-scale operations could eventually exceed the assimilative capacity of offshore ecosystems. Additionally, high-density farming of carnivorous species demands substantial volumes of feed derived from wild forage fish, raising concerns about the sustainability of feed supply chains. Disease transmission between cultured and wild fish populations remains a significant uncertainty, as does the potential for escapes that could alter local genetic stocks or introduce pathogens. Thus, ongoing research and adaptive management are critical to addressing the environmental risks inherent in scaling up offshore production.

Fish Escapes and Biosecurity Concerns

The economic imperative to avoid stock losses makes preventing fish escapes a central concern in offshore aquaculture. Submersible cages are designed as fully closed systems; nonetheless, the potential for structural damage during storms or from predator attacks can lead to unintentional releases. Even when farmed species are native to the region, escapes may pose ecological risks by altering local gene pools or outcompeting wild fish for resources. Furthermore, the eggs of some species, such as cod, can pass through mesh netting and establish themselves in the wild. To counteract these risks, offshore cage designs employ high-tensile materials and rigorous maintenance regimes. However, as production scales up, maintaining consistently effective containment will remain a logistical and engineering challenge.

Disease Management and Health Considerations

Compared to inshore aquaculture, offshore farms often experience lower disease incidence, largely due to greater water exchange and the physical separation of farming units. For example, offshore-cultured mussels have demonstrated markedly lower parasitic loads than their inshore counterparts. Nevertheless, many of the species targeted for offshore production are relatively new to aquaculture, and their epidemiology in open ocean settings is poorly understood. The risk of pathogen transfer between cultured populations and wild stocks remains

a major unresolved question, particularly if mobile cage systems are adopted. Additionally, sourcing live broodstock, bait, and milt from wild populations can inadvertently introduce disease agents, emphasizing the need for strict biosecurity protocols and comprehensive health monitoring frameworks.

Socioeconomic and Regulatory Dimensions

Aquaculture is increasingly viewed by governments as a means to generate income and employment, especially in regions facing declining wild fish stocks. However, offshore aquaculture's high capital and operating costs can drive automation and reduce direct employment opportunities relative to traditional nearshore systems. As a result, job growth may be concentrated in processing and distribution rather than farm operations. In the United States, regulatory complexity further complicates offshore development: coastal states typically control waters within 3 nautical miles of shore, while federal jurisdiction applies beyond that limit, up to 200 nautical miles. Despite demonstration projects and research initiatives in Hawaii, California, New Hampshire, and Puerto Rico, unclear permitting processes and technical uncertainties have slowed widespread adoption. Legislative efforts, such as the National Sustainable Offshore Aquaculture Act of 2011, have aimed to establish coherent regulatory frameworks to enable commercial offshore production.

Global Adoption and Current Practices

By 2005, offshore aquaculture ventures were underway in 25 countries, spanning both commercial and experimental initiatives. European nations have embraced offshore aquaculture as part of strategies to expand seafood production while alleviating inshore pressures. Norway, Ireland, Spain, and Portugal have invested in offshore cage technologies and sensor systems for feeding, health monitoring, and environmental assessment. In the United States and the Bahamas, submersible cages have been used to cultivate high-value carnivorous finfish such as cobia, mutton snapper, and moi. Shellfish cultivation, particularly mussels and scallops grown in suspended culture systems, has gained prominence due to lower feed costs and resilience to offshore conditions. Research from the University of New Hampshire has demonstrated that mussels farmed offshore often yield higher meat content and improved quality compared to inshore farms.

Future Prospects and Research Needs

The Food and Agriculture Organization has underscored the inevitability of aquaculture's

expansion into offshore environments to meet escalating seafood demands. However, the organization has also emphasized caution, advocating for the development of appropriate technologies and assessment frameworks to minimize ecological risks. Future offshore farms are likely to integrate advanced remote monitoring systems, automated feeding platforms, and robust cage structures adapted from offshore oil and gas engineering. Clarifying legal definitions, harmonizing regulations, and supporting developing countries in adopting offshore aquaculture technologies are critical priorities. Research on ecological thresholds for nutrient assimilation, disease dynamics in open ocean systems, and the socioeconomic implications of large-scale offshore aquaculture will be essential to ensure sustainable and equitable growth of this sector.

Conclusion

Offshore aquaculture stands at the frontier of modern seafood production, offering opportunities to relieve pressure on wild fisheries and increase global protein supply. While substantial progress has been made in engineering and operations, critical knowledge gaps remain regarding the environmental and social consequences of farming in offshore waters. By combining technological innovation, rigorous scientific research, and sound governance, offshore aquaculture can evolve into a cornerstone of sustainable ocean food systems.

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PLANT GROWTH-PROMOTING RHIZOBACTERIA: A SUSTAINABLE APPROACH TO PLANT HEALTH AND DISEASE MANAGEMENT

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Abstract

In the face of growing environmental concerns, chemical-intensive farming practices are becoming unsustainable. Plant Growth-Promoting Rhizobacteria (PGPR) offer an eco-friendly, cost-effective, and sustainable solution to boost crop production and combat plant diseases. Plant Growth-Promoting Rhizobacteria (PGPR) are a diverse group of soil bacteria that colonize plant roots and enhance plant growth and health through a variety of mechanisms. Their influence extends from nutrient acquisition and hormone modulation to robust biocontrol of plant pathogens, making them essential for sustainable agriculture and integrated disease management.

Introduction

Plant Growth-Promoting Rhizobacteria (PGPR) are a diverse group of beneficial soil bacteria that inhabit the rhizosphere the thin, nutrient-rich layer of soil surrounding plant roots and play a crucial role in enhancing plant growth and health. These microorganisms colonize plant roots and contribute to plant development through multiple mechanisms, including improving nutrient uptake, producing phytohormones, and protecting plants from pathogens. The rhizosphere is a zone of intense microbial activity, where the concentration of bacteria around roots is 10 to 100 times higher than in the surrounding bulk soil, largely due to the presence of root exudates that serve as nutrient sources for microbes. Among the various microorganisms present, bacteria are the most abundant and influential in promoting plant growth. The term "plant growth-promoting rhizobacteria" was first introduced by Kloepper and Schroth in the late 1970s and has since become widely used in scientific literature. PGPR can directly stimulate plant growth by solubilizing phosphates, fixing atmospheric nitrogen, and producing plant

hormones such as auxins and cytokinins. They also indirectly benefit plants by suppressing plant pathogens through competition, production of antimicrobial substances, and induction of systemic resistance in the host plant. These dual roles make PGPR valuable as biofertilizers and biocontrol agents, offering an eco-friendly alternative to chemical fertilizers and pesticides. With increasing concerns about the environmental impact and rising costs of synthetic agrochemicals, the use of PGPR is gaining global attention as a key strategy for sustainable agriculture, improved soil fertility, and enhanced crop productivity.

Diversity and Ecology of PGPR

Rhizosphere as a Hotspot: The rhizosphere, a narrow region of soil influenced by root exudates, is a dynamic environment where PGPR thrive and interact with plants, pathogens, and other microbes.

Bacterial Genera: Common PGPR genera *include Pseudomonas, Bacillus, Azospirillum, Azotobacter, Rhizobium, Enterobacter, Serratia,* and *Burkholderia,* among others.

Microbial Community: Only 2–5% of rhizosphere bacteria are PGPR, but their impact on plant health and soil fertility is significant.

Mechanisms of Plant Growth Promotion by PGPR

1. Direct Mechanisms

Nitrogen Fixation: PGPR such as Azospirillum, Azotobacter, and Rhizobium convert atmospheric nitrogen into forms usable by plants, reducing the need for synthetic fertilizers.

Phosphate Solubilisation: Many PGPR solubilize insoluble phosphates through the secretion of organic acids and phosphatases, making phosphorus more available to plants.

Phytohormone Production:

Auxins (e.g., IAA): Stimulate root elongation, branching, and overall root architecture, enhancing nutrient and water uptake.

Gibberellins and Cytokinins: Promote shoot growth, cell division, and differentiation, and interact with auxins to regulate root and shoot development.

ACC Deaminase Activity: PGPR produce ACC deaminase, which lowers plant ethylene levels, mitigating stress responses and promoting root growth under adverse conditions.

Exopolysaccharide (EPS) Production: EPS aids in biofilm formation, root colonization, and protection against desiccation and environmental stress.

2. Indirect Mechanisms

Siderophore Production: PGPR secrete siderophores that chelate iron, depriving pathogens of this essential nutrient and inhibiting their growth.

Antibiotic and VOC Production: Many PGPR produce antibiotics and volatile organic compounds (VOCs) that directly suppress pathogens.

Enzyme Secretion: Lytic enzymes such as chitinases and glucanases degrade pathogen cell walls, providing direct protection to plants.

Hydrogen Cyanide (HCN) Production: Some PGPR produces HCN, which is toxic to certain pathogens and weeds, contributing to biocontrol.

Induced Systemic Resistance (ISR): PGPR trigger plant defence pathways, priming the plant for enhanced resistance to a broad spectrum of pathogens through signalling molecules like jasmonic acid and ethylene.

PGPR in Plant Disease Management: Biocontrol Mechanisms

1. Antibiosis

Antibiosis refers to the ability of PGPR to produce and release antimicrobial compounds (such as antibiotics, bacteriocins, and volatile organic compounds) into the rhizosphere. These substances can directly inhibit the growth or kill plant pathogens, including harmful bacteria, fungi, and even some nematodes.

How it works: When PGPR colonize the root zone, they secrete these bioactive compounds, which either prevent the pathogens from multiplying or destroy them outright. For example, some strains of *Pseudomonas fluorescens* produce antibiotics like phenazine and pyoluteorin that are toxic to soil-borne fungal pathogens.

Result: The presence of these antimicrobial substances reduces the population of disease-causing organisms in the soil, lowering the risk of infection.

2. Competition

Competition is another important biocontrol mechanism. PGPR compete with pathogens for limited resources such as nutrients (especially iron) and physical space in the rhizosphere.

How it works: PGPR are often fast-growing and efficient at colonizing root surfaces. By occupying the root zone and utilizing available nutrients, they leave little room or resources for pathogenic microbes to establish themselves.

Siderophore production: Many PGPR produce siderophores—molecules that bind iron more effectively than those produced by pathogens. This deprives pathogens of the iron they need to grow.

Result: The competitive exclusion of pathogens helps prevent their proliferation and reduces disease incidence.

3. Parasitism

Parasitism involves some PGPR directly attacking and parasitizing plant pathogens, particularly pathogenic fungi.

How it works: Certain PGPR can produce enzymes such as chitinases and glucanases that degrade the cell walls of fungal pathogens. By breaking down these structural components, the bacteria effectively kill or inhibit the growth of the fungi.

Example: Some *Bacillus* species can parasitize and lyse the hyphae of soil-borne fungi like *Fusarium* and *Rhizoctonia*.

Result: This direct antagonism reduces the population of pathogenic fungi in the soil, providing a protective effect for the plant.

4. ISR Activation (Induced Systemic Resistance)

Induced Systemic Resistance (ISR) is a process by which PGPR stimulate the plant's own immune system, making it more resistant to a wide range of pathogens.

How it works: PGPR interact with plant roots and trigger signalling pathways (involving hormones like jasmonic acid and ethylene) that activate defence genes throughout the plant—even in tissues far from the roots.

Defence responses: This leads to the production of pathogenesis-related proteins, phytoalexins, and strengthening of cell walls, all of which help the plant fend off future attacks by pathogens.

Result: ISR does not directly kill pathogens but primes the plant for a faster and stronger defence response upon pathogen attack, reducing disease severity and spread.

Examples of PGPR in Disease Management

PGPR Species	Target Pathogen/Disease	Mechanism of Action
Pseudomonas fluorescens	*Fusarium* wilt, root rot, bacterial spot	Antibiotics, siderophores, ISR, VOCs
Bacillus subtilis	*Rhizoctonia solani*, foliar pathogens	Lipopeptides, enzyme production, ISR

Bacillus amyloliquefaciens	Damping-off, *Fusarium* spp.	Antagonism, ISR, VOCs
Rhizobium spp.	Legume root pathogens	Nitrogen fixation, ISR
Serratia liquefaciens	*Alternaria alternata*	AHL-mediated ISR

Molecular and Cellular Insights

Signal Exchange: Plants and PGPR communicate via root exudates and bacterial signal molecules, shaping the rhizosphere community and modulating plant responses.

Biofilm Formation: PGPR form biofilms on root surfaces, enhancing colonization, persistence, and biocontrol efficacy.

Gene Regulation: PGPR can induce transcriptional changes in plant genes related to hormone signalling, defence, and cell wall modification.

Ecological and Environmental Benefits

Reduced Chemical Inputs: PGPR reduce the need for chemical fertilizers and pesticides, lowering environmental pollution and production costs.

Enhanced Stress Tolerance: PGPR help plants withstand abiotic stresses such as drought, salinity, and heavy metal toxicity, contributing to resilience under climate change.

Soil Health Improvement: By promoting nutrient cycling and suppressing pathogens, PGPR enhance soil fertility and structure.

Challenges and Future Prospects

Field Variability: The efficacy of PGPR can be inconsistent under field conditions due to soil type, climate, and native microbial communities.

Formulation and Delivery: Developing stable, effective PGPR formulations with high rhizosphere colonization rates remains a challenge.

Integration with Other Microbes: Synergistic interactions between PGPR, mycorrhizal fungi, and nitrogen-fixing bacteria can further enhance plant growth and disease resistance.

Conclusion

PGPR are indispensable allies in sustainable agriculture, offering a multifaceted approach to plant growth promotion and disease management. Their ability to enhance nutrient uptake, modulate plant hormones, suppress pathogens, and induce systemic resistance positions them as a cornerstone of eco-friendly crop production strategies. Continued research and technological

advances are expected to further unlock the potential of PGPR for global food security and environmental sustainability.

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REVERSE TRANSCRIPTION POLYMERASE CHAIN REACTION (RT-PCR) IN PLANT PATHOLOGY

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Introduction

Reverse transcription polymerase chain reaction (RT-PCR) is a laboratory technique combining reverse transcription of RNA into DNA (in this context called complementary DNA or cDNA) and amplification of specific DNA targets using polymerase chain reaction (PCR). It is primarily used to measure the amount of a specific RNA. This is achieved by monitoring the amplification reaction using fluorescence, a technique called real-time PCR or quantitative PCR (qPCR). Combined RT-PCR and qPCR are routinely used for analysis of gene expression and quantification of viral RNA in research and clinical settings.

RT-PCR

The close association between RT-PCR and qPCR has led to metonymic use of the term qPCR to mean RT-PCR. Such use may be confusing as RT-PCR can be used without qPCR, for example to enable molecular cloning, sequencing or simple detection of RNA. Conversely, qPCR may be used without RT-PCR, for example to quantify the copy number of a specific piece of DNA.

Contents

The combined RT-PCR and qPCR technique has been described as quantitative RT-PCR or real-time RT-PCR(sometimes even called quantitative real-time RT-PCR, has been variously abbreviated as qRT-PCR, RT-qPCR, RRT-PCR, and rRT-PCR. In order to avoid confusion, the following abbreviations will be used consistently throughout this article:

Technique	Abbreviation
Polymerase chain reaction	PCR
Reverse transcription polymerase chain reaction	RT-PCR
Real-time polymerase chain reaction	qPCR
RT-PCR / qPCR combined technique	qRT-PCR

Not all authors, especially earlier ones, use this convention and the reader should be cautious when following links. RT-PCR has been used to indicate both real-time PCR (qPCR) and reverse transcription PCR (RT-PCR).

History

Since its introduction in 1977, Northern blot has been used extensively for RNA quantification despite its shortcomings: (a) time-consuming technique, (b) requires a large quantity of RNA for detection, and (c) quantitatively inaccurate in the low abundance of RNA content. However, since PCR was invented by Kary Mullis in 1983, RT PCR has since displaced Northern blot as the method of choice for RNA detection and quantification. RT-PCR has risen to become the benchmark technology for the detection and/or comparison of RNA levels for several reasons: (a) it does not require post PCR processing, (b) a wide range (>107-fold) of RNA abundance can be measured, and (c) it provides insight into both qualitative and quantitative data.

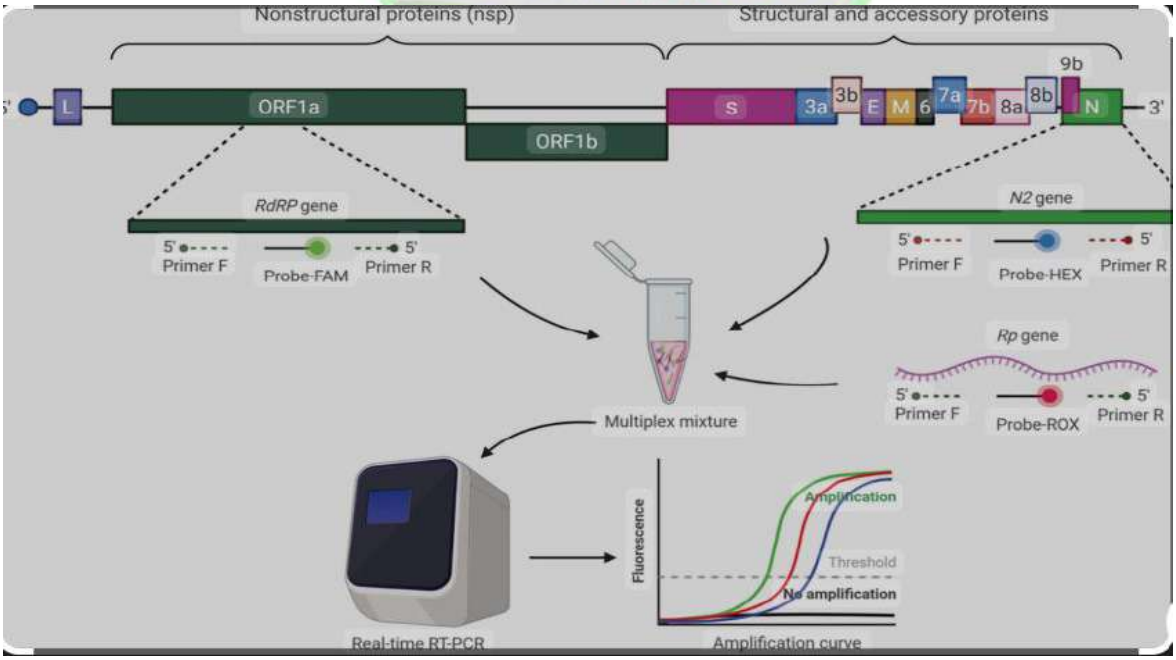


Fig1. Schematic representation of RT-PCR

Principles

In RT-PCR, the RNA template is first converted into a complementary DNA (cDNA) using a reverse transcriptase (RT). The cDNA is then used as a template for exponential amplification using PCR. The use of RT-PCR for the detection of RNA transcript has revolutionized the study of gene expression in the following important ways: Made it theoretically possible to detect the transcripts of practically any gene. Enabled sample amplification and eliminated the need for abundant starting material required when using northern blot analysis. Provided tolerance for RNA degradation as long as the RNA spanning the primer is intact.

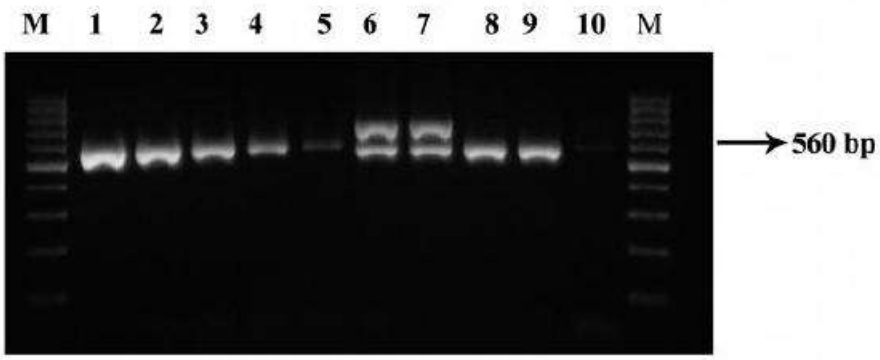


Fig2. Agarose gel electrophoresis of different gene amplicons from 10 fold diluted standard samples

One-step RT-PCR vs two-step RT-PCR

The quantification of mRNA using RT-PCR can be achieved as either a one-step or a two-step reaction. The difference between the two approaches lies in the number of tubes used when performing the procedure. The two-step reaction requires that the reverse transcriptase reaction and PCR amplification be performed in separate tubes. The disadvantage of the two-step approach is susceptibility to contamination due to more frequent sample handling.On the other hand, the entire reaction from cDNA synthesis to PCR amplification occurs in a single tube in the one-step approach. The one-step approach is thought to minimize experimental variation by containing all of the enzymatic reactions in a single environment. It eliminates the steps of pipetting cDNA product, which is labor-intensive and prone to contamination, to PCR reaction. However, the starting RNA templates are prone to degradation in the one-step approach, and the use of this approach is not recommended when repeated assays from the same sample is required. Additionally, the one-step approach is reported to be less accurate compared to the two-

step approach. It is also the preferred method of analysis when using DNA binding dyes such as SYBR Green since the elimination of primer-dimers can be achieved through a simple change in the melting temperature. Nevertheless, the one-step approach is a relatively convenient solution for the rapid detection of target RNA directly in biosensing.

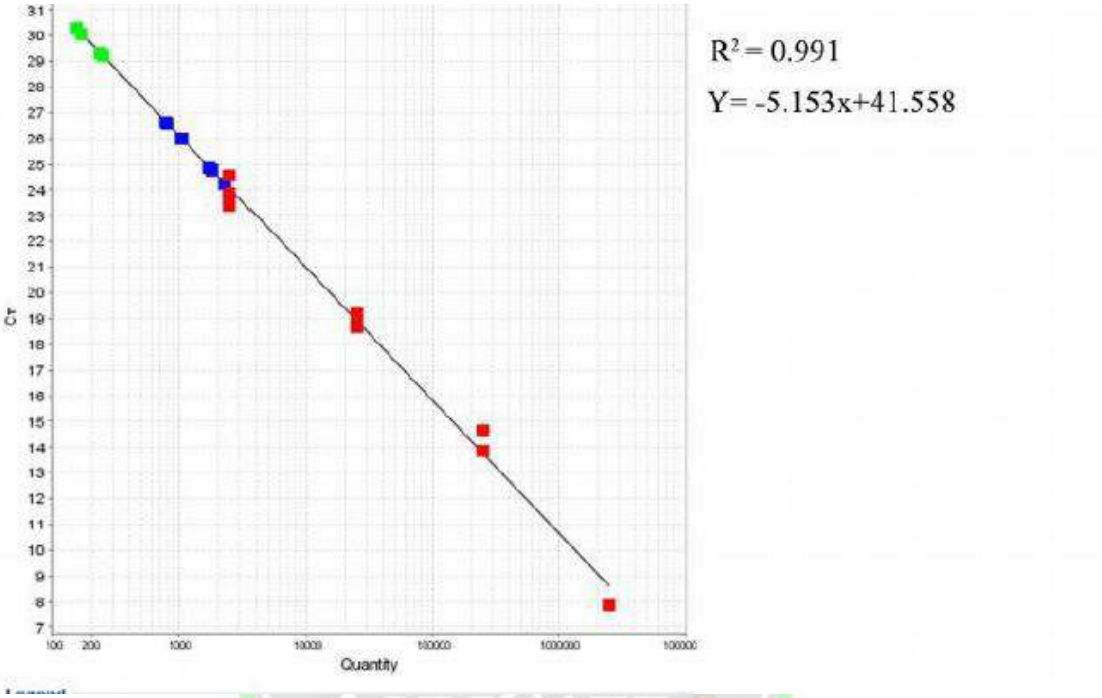


Fig 3. Standard curve generated during qPCR using SYBR greendye for copy number of ITS region against threshold cycle

End-point RT-PCR vs real-time RT-PCR

Quantification of RT-PCR products can largely be divided into two categories: end-point and real-time.The use of end-point RT-PCR is preferred for measuring gene expression changes in small number of samples, but the real-time RT-PCR has become the gold standard method for validating quantitative results obtained from array analyses or gene expression changes on a global scale.

End-point RT-PCR

The measurement approaches of end-point RT-PCR requires the detection of gene expression levels by the use of fluorescent dyes like ethidium bromide, P32 labeling of PCR products using phosphorimager,or by scintillation counting. End-point RT-PCR is commonly achieved using three different methods: relative, competitive and comparative.

Relative RT-PCR

Relative quantifications of RT-PCR involves the co-amplification of an internal control simultaneously with the gene of interest. The internal control is used to normalize the samples. Once normalized, a direct comparison of relative transcript abundances across multiple samples of mRNA can be made. One precaution to note is that the internal control must be chosen so that it is not affected by the experimental treatment. The expression level should be constant across all samples and with the mRNA of interest for the results to be accurate and meaningful. Because the quantification of the results are analyzed by comparing the linear range of the target and control amplification, it is crucial to take into consideration the starting target molecules concentration and their amplification rate prior to starting the analysis. The results of the analysis are expressed as the ratios of gene signal to internal control signal, which the values can then be used for the comparison between the samples in the estimation of relative target RNA expression.

Competitive RT-PCR

Competitive RT-PCR technique is used for absolute quantification. It involves the use of a synthetic "competitor" RNA that can be distinguished from the target RNA by a small difference in size or sequence. It is important for the design of the synthetic RNA be identical in sequence but slightly shorter than the target RNA for accurate results. Once designed and synthesized, a known amount of the competitor RNA is added to experimental samples and is co-amplified with the target using RT-PCR. Then, a concentration curve of the competitor RNA is produced and it is used to compare the RT-PCR signals produced from the endogenous transcripts to determine the amount of target present in the sample.

Comparative RT-PCR

Comparative RT-PCR is similar to the competitive RT-PCR in that the target RNA competes for amplification reagents within a single reaction with an internal standard of unrelated sequence. Once the reaction is complete, the results are compared to an external standard curve to determine the target RNA concentration. In comparison to the relative and competitive quantification methods, comparative RT-PCR is considered to be the more convenient method to use since it does not require the investigator to perform a pilot experiment; in relative RT-PCR, the exponential amplification range of the mRNA must be predetermined and in competitive RT-PCR, a synthetic competitor RNA must be synthesized.

Real-time RT-PCR

The emergence of novel fluorescent DNA labeling techniques in the past few years has enabled the analysis and detection of PCR products in real-time and has consequently led to the widespread adoption of real-time RT-PCR for the analysis of gene expression. Not only is real-time RT-PCR now the method of choice for quantification of gene expression, it is also the preferred method of obtaining results from array analyses and gene expressions on a global scale. Currently, there are four different fluorescent DNA probes available for the real-time RT-PCR detection of PCR products: SYBR Green, TaqMan, molecular beacons, and scorpion probes. All of these probes allow the detection of PCR products by generating a fluorescent signal. While the SYBR Green dye emits its fluorescent signal simply by binding to the double-stranded DNA in solution, the TaqMan probes', molecular beacons' and scorpions' generation of fluorescence depend on Förster Resonance Energy Transfer (FRET) coupling of the dye molecule and a quencher moiety to the oligonucleotide substrates.

SYBR Green

When the SYBR Green binds to the double-stranded DNA of the PCR products, it will emit light upon excitation. The intensity of the fluorescence increases as the PCR products accumulate. This technique is easy to use since designing of probes is not necessary given lack of specificity of its binding. However, since the dye does not discriminate the double-stranded DNA from the PCR products and those from the primer-dimers, overestimation of the target concentration is a common problem. Where accurate quantification is an absolute necessity, further assay for the validation of results must be performed. Nevertheless, among the real-time RT-PCR product detection methods, SYBR Green is the most economical and easiest to use.

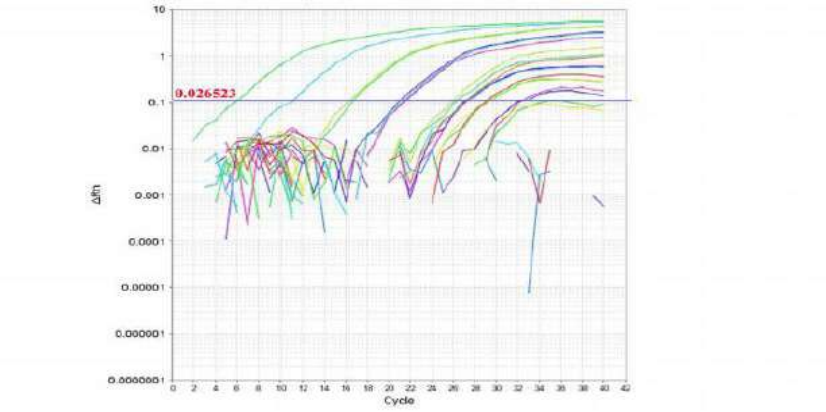


Fig 4. Amplification plot generated during qPCR of fungal ITS gene

TaqMan probes

TaqMan probes are oligonucleotides that have a fluorescent probe attached to the 5' end and a quencher to the 3' end. During PCR amplification, these probes will hybridize to the target sequences located in the amplicon and as polymerase replicates the template with TaqMan bound, it also cleaves the fluorescent probe due to polymerase 5'- nuclease activity. Because the close proximity between the quench molecule and the fluorescent probe normally prevents fluorescence from being detected through FRET, the decoupling results in the increase of intensity of fluorescence proportional to the number of the probe cleavage cycles. Although well-designed TaqMan probes produce accurate real-time RT-PCR results, it is expensive and time-consuming to synthesize when separate probes must be made for each mRNA target analyzed. Additionally, these probes are light sensitive and must be carefully frozen as aliquots to prevent degradation.

Molecular beacon probes

Similar to the TaqMan probes, molecular beacons also make use of FRET detection with fluorescent probes attached to the 5' end and a quencher attached to the 3' end of an oligonucleotide substrate. However, whereas the TaqMan fluorescent probes are cleaved during amplification, molecular beacon probes remain intact and rebind to a new target during each reaction cycle. When free in solution, the close proximity of the fluorescent probe and the quencher molecule prevents fluorescence through FRET. However, when molecular beacon probes hybridize to a target, the fluorescent dye and the quencher are separated resulting in the emittance of light upon excitation. As is with the TaqMan probes, molecular beacons are expensive to synthesize and require separate probes for each RNA target.

Scorpion probes

The scorpion probes, like molecular beacons, will not be fluorescent active in an unhybridized state, again, due to the fluorescent probe on the 5' end being quenched by the moiety on the 3' end of an oligonucleotide. With Scorpions, however, the 3' end also contains sequence that is complementary to the extension product of the primer on the 5' end. When the Scorpion extension binds to its complement on the amplicon, the Scorpion structure opens, prevents FRET, and enables the fluorescent signal to be measured.

Multiplex probes

TaqMan probes, molecular beacons, and scorpions allow the concurrent measurement of

PCR products in a single tube. This is possible because each of the different fluorescent dyes can be associated with a specific emission spectra. Not only does the use of multiplex probes save time and effort without compromising test utility, its application in wide areas of research such as gene deletion analysis, mutation and polymorphism analysis, quantitative analysis, and RNA detection, make it an invaluable technique for laboratories of many discipline. Two strategies are commonly employed to quantify the results obtained by real-time RT-PCR; the standard curve method and the comparative threshold method.

Application

The exponential amplification via reverse transcription polymerase chain reaction provides for a highly sensitive technique in which a very low copy number of RNA molecules can be detected. RT-PCR is widely used in the diagnosis of diseases and, semi quantitatively, in the determination of the abundance of specific different RNA molecules within a cell or tissue as a measure of gene expression.

Research methods

RT-PCR is commonly used in research methods to measure gene expression. For example, Lin et al. used qRT-PCR to measure expression of Gal genes in yeast cells. First, Lin et al. engineered a mutation of a protein suspected to participate in the regulation of Gal genes. This mutation was hypothesized to selectively abolish Gal expression. To confirm this, gene expression levels of yeast cells containing this mutation were analyzed using qRT-PCR. The researchers were able to conclusively determine that the mutation of this regulatory protein reduced Gal expression.Northern blot analysis is used to study the RNA's gene expression further.

Gene insertion

RT-PCR can also be very useful in the insertion of eukaryotic genes into prokaryotes. Because most eukaryotic genes contain introns, which are present in the genome but not in the mature mRNA, the cDNA generated from a RT-PCR reaction is the exact (without regard to the error-prone nature of reverse transcriptases) DNA sequence that would be directly translated into protein after transcription. When these genes are expressed in prokaryotic cells for the sake of protein production or purification, the RNA produced directly from transcription need not undergo splicing as the transcript contains only exons. (Prokaryotes, such as E. coli, lack the mRNA splicing mechanism of eukaryotes).

Challenges

Despite its major advantages, RT-PCR is not without drawbacks. The exponential growth of the reverse transcribed complementary DNA (cDNA) during the multiple cycles of PCR produces inaccurate end point quantification due to the difficulty in maintaining linearity. In order to provide accurate detection and quantification of RNA content in a sample, qRT-PCR was developed using fluorescence-based modification to monitor the amplification products during each cycle of PCR. The extreme sensitivity of the technique can be a double edged sword since even the slightest DNA contamination can lead to undesirable results.A simple method for elimination of false positive results is to include anchors, or tags, to the 5' region of a gene specific primer. Additionally, planning and design of quantification studies can be technically challenging due to the existence of numerous sources of variation including template concentration and amplification efficiency. Spiking in a known quantity of RNA into a sample, adding a series of RNA dilutions generating a standard curve, and adding in a no template copy sample (no cDNA) may used as controls.

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THE ART OF MOLECULAR MANIPULATION

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Abstract

This explores the burgeoning field of molecular manipulation not merely as a scientific endeavor, but as a nascent art form. Drawing parallels between traditional artistic practices and the precise control over atoms and molecules, we propose that the deliberate arrangement of matter at the nanoscale transcends mere engineering to become an act of creative expression. While rooted in principles of chemistry, physics, and biology, the "artist" in this context utilizes advanced instrumentation – such as scanning probe microscopes, optical tweezers, and directed self-assembly techniques – as their brushes and chisels. The "canvas" encompasses the vast landscape of molecular structures, where the arrangement of individual atoms, the formation of novel compounds, or the construction of intricate nanomachines represents a unique aesthetic. This abstract will briefly touch upon the historical progression of atomic-scale control, highlight contemporary examples of molecular construction that demonstrate artistic intent (e.g., molecular machines, DNA origami sculptures, and bespoke catalytic architectures), and discuss the philosophical implications of creating beauty and function from the fundamental building blocks of the universe. Ultimately, we posit that the art of molecular manipulation offers a new frontier for human creativity, where the boundaries between science, technology, and artistic expression become increasingly blurred, promising a future where matter itself is a medium for artistic genius.

Introduction

The art of molecular manipulation, often referred to as nanotechnology or molecular

engineering, is a fascinating and rapidly evolving field that involves the precise control and alteration of matter at the atomic and molecular level. It's about building things from the ground up, atom by atom, or molecule by molecule, rather than relying on traditional macroscopic fabrication methods.

At its core, molecular manipulation aims to harness the fundamental building blocks of the universe – atoms and molecules – to create new materials, devices, and systems with unprecedented properties and functionalities. This isn't just about mixing chemicals; it's about deliberately arranging individual atoms to achieve a desired outcome.

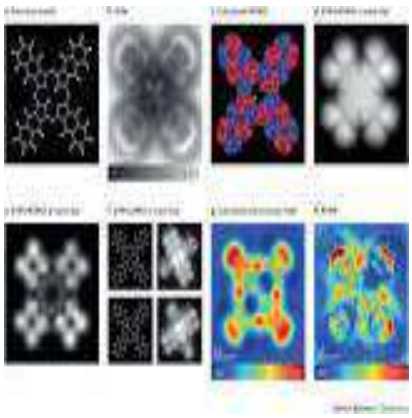
The concept itself has roots in a 1959 speech by physicist Richard Feynman titled "There's Plenty of Room at the Bottom," where he envisioned a future where scientists could precisely control and move individual atoms. While initially a theoretical concept, advancements in microscopy, computing, and synthetic chemistry have brought this "art" closer to reality.

Key to this field are tools and techniques that allow us to visualize, interact with, and manipulate matter at the nanoscale (typically 1 to 100 nanometers). This includes instruments like scanning tunneling microscopes (STMs) and atomic force microscopes (AFMs), which can not only image individual atoms but also be used to push them around.

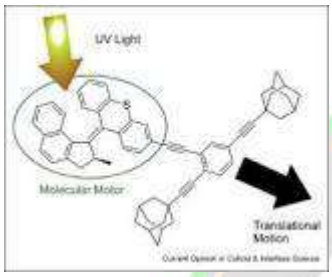
The potential applications of molecular manipulation are vast and transformative, spanning areas such as:

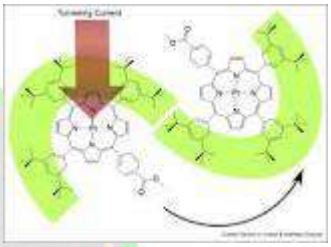
1) Medicine: Targeted drug delivery, molecular diagnostics, tissue engineering, and even molecular-scale surgical tools.
2) Materials Science: Creating materials with enhanced strength, conductivity, or novel optical properties; self-assembling materials.
3) Electronics: Developing smaller, faster, and more efficient electronic components.
4) Energy: More efficient solar cells, novel energy storage solutions.
5) Environmental Remediation: Nanofiltration for water purification, catalysts for pollutant breakdown.

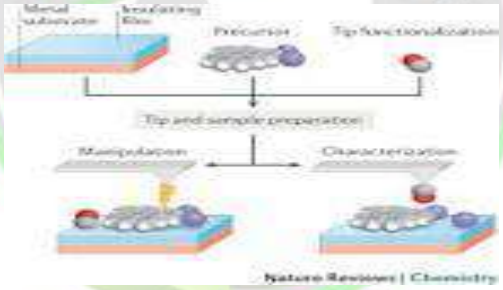
While still in its early stages for many of its more ambitious goals (like true "assemblers" that build anything atom by atom), the art of molecular manipulation is continuously pushing the boundaries of what's possible, promising a future where we have unparalleled control over the material world around us.











Conclusion

The "art of molecular manipulation" represents a frontier where scientific ingenuity converges with the precise control of matter at its most fundamental level. Far from a mere scientific discipline, it embodies a profound creative endeavor, akin to an artist meticulously crafting a masterpiece, yet here the medium is atoms and molecules, and the canvas is the very fabric of existence. This intricate art form is driven by a deep understanding of chemical bonds, intermolecular forces, and quantum mechanics, allowing for the deliberate arrangement and rearrangement of molecular structures. From the targeted synthesis of novel pharmaceuticals and advanced materials to the development of highly efficient catalysts and the burgeoning fields of nanotechnology and molecular machines, the ability to precisely dictate molecular architecture underpins transformative advancements across virtually every scientific and technological

domain. The implications of mastering this art are vast and continue to unfold. We are moving towards a future where diseases might be cured at their molecular root, where materials possess unprecedented strength-to-weight ratios or self-healing properties, and where energy generation and storage become orders of magnitude more efficient.

However, like any powerful art, it demands not only technical virtuosity but also profound ethical consideration, emphasizing the critical need for responsible innovation as we continue to push the boundaries of what is possible in the molecular realm. The art of molecular manipulation is not just about what we can build, but what we choose to build, and the future it shapes.

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MANAGEMENT STRATERGIES FOR INSECTS AND NON-INSECT PESTS OF TOMATO.

Article ID: AG-V05-I07-43

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Introduction

Tomato *(Solanum lycopersicum*) is one of the most widely grown and consumed vegetables in the world, often used in a variety of culinary dishes. It is technically a fruit, but it is commonly classified as a vegetable in cooking due to its savory flavor. Tomatoes are a major agricultural crop, with top producers including China, India, the United States, and countries in the European Union. Fresh tomatoes are sold in markets, but a large portion is used for processed products like ketchup, sauces, juices, and canned tomatoes. Tomatoes are a high-value crop, often bringing good returns to farmers, especially if they can be sold directly to local markets or processed into value-added products.

Fruit Borer, *Helicoverpa armigera* (Noctuidae; Lepidoptera)

Distribution: South America

Host: Cotton, Groundnut and Cowpea

Symptoms of damage:

- Young larvae feed on tender foliage
- Mature larvae bore circular holes
- Thrust only a part of its body into fruit and eat the inner content

Identification of pest:

- Eggs: Eggs are sculptured and creamy white in colour, laid singly
- Larva: Shows colour variation from greenish to brown. It has dark brown grey lines on the body with lateral white lines and also has dark band

- Pupa: Brown in colour, occurs in soil, leaf, pod and crop debris
- Adult: Female light pale brownish yellow stout moth, Male – Pale greenish moth V shaped speck.
- Forewing: olive green to pale brown with a dark brown circular spot in the centre
- Hindwing: pale smoky white with a broad blackish outer margin

Management:

- Collect and destroy the infected fruits and grown up larvae
- Grow simultaneously 40 days old American tall marigold and 25 days old tomato seedling at 1:16 rows
- Setup pheromone trap with Helilure at 12/ha
- Collection and destroy of damaged fruits and grown up caterpillars.
- Release *Trichogramma pretiosum* @ 1 lakh/ha at an interval of 7 days starting from flower initiation stage.
- Spray HaNPV 1.5 x 1012 POBs/ha.
- For *Helicoverpa armigera*: HaNPV 1.5 x 1012 POBs/ha i.e. NPV of H. armigera 0.43% AS @ 3.0 ml/lit or 2 % AS @ 1.0 ml per lit
- For Spodoptera litura: Sl NPV 1.5 x 1012 POBs/ha
- Provide poison bait with carbaryl 50 WP 1.25 kg, rice bran 12.5 kg, jaggery 1.25 kg and water 7.5 lit/ha
- Spray *Bacillus thuringiensis* 2g/lit or any one of the following insecticide
- Spray Azadirachtin 1.0 % EC (10000 ppm) 2.0 ml/ lit. or apply Bacillus thuringiensis 2g/lit. during evening hours.
- Pesticide- Indoxacarb 14.5 SC8 ml/ 10 lit, Flubendiamide 39.35 SC2 ml/10 lit, Flubendiamide 20 WG2 g/10 lit, Novaluron 10 % EC7.5 ml/10 lit, Phosalone 35 % EC13 ml/10 lit, Quinalphos 25 % EC1.0 ml/ lit, Chlorantraniliprole 18.5 SC3.0 ml/ 10 lit, Cyantraniliprole 10.26 OD18 ml/ 10 lit

Serpentine leaf miner, *Liriomyza trifolii* (Agromyzidae; Diptera)

Distribution: Pacific, America and Africa.

Symptoms of damage:

- Leaves with serpentine mines
- Drying and dropping of leaves

Identification of pest:

- Larva: Minute orange yellowish apodous maggots
- Pupa: Yellowish brown pupates within mines
- Adult: Pale yellow in colour

Management:

- Collect and destroy mined leaves
- Spray NSKE 5%
- Spray Neem Seed Kernel Extract 5 %.
- Cyantraniliprole 10.26 OD 1.8ml/lit.

Leaf eating caterpillar, *Spodoptera litura* (Noctuidae; Lepidoptera)

Distribution: India, Burma, Bangladesh, Srilanka.

Host: Groundnut

Symptoms of damage:

- Young larva scrap leaves on ventral surface
- Grownups defoliate crops

Identification of pest:

Egg: Masses appear golden brown

Larva: Pale greenish with dark markings, gregarious in the early stages

Adult: Brownish in colour, Forewings are brown colour with wavy white marking, Hind wings are white colour with a brown patch along the margin

Management:

- Grow castor as trap crop. Collect and destroy egg masses and early instar larvae
- Set up pheromone traps @ 12/ha.
- Spray SlNPV 1.5 x 1012 POBs/ha
- Spray Azadirachtin 1.0 % EC (10000 ppm) 2.0 ml/ lit. or apply Bacillus thuringiensis 2g/lit. during evening hours.
- Plough the soil to expose and kill the pupae
- Grow castor along border and irrigation channel as trap crop
- Set up light trap @1/ha
- Pheromone traps (Pherodin SL) @15/ ha to attract male moths
- Collect and destroy egg masses in castor and tomato

- Hand pick grown up larvae and kill them
- Spray Sl NPV @ 1.5 X 1012 POBs / ha+2.5 Kg crude sugar+0.1 % teepol
- Poison bait: Rice bran 5 Kg + Molasses or Brown sugar 500g + Carbaryl 50 WP 500g+ 3lit of water/ha. Mix the ingredients well and are kept around the field in the evening hours
- Spray chlorpyriphos 20 EC 2 lit/ha or dichlorovos 76 WSC 1 lit/ha

Whitefly, *Bemisia tabaci* (Aleyrodidae; Hemiptera)

Distribution: Tropical regions

Host: Guava, Coconut

Symptoms of damage:

- Chlorotic spots and Yellowing
- Downward curling and drying of leaves
- Vector of tomato leaf curl disease

Identification of pest:

- Egg: Pear shaped, light yellowish, stalked
- Nymph: On hatching - Oval, scale-like, greenish white
- Adult: White, tiny, scale-like adults

Management:

- Install yellow sticky traps @ 12 /ha to attract the adult.
- Remove alternate weed host Abutilon indicum.
- Uproot and destroy the diseased leaf curl plants
- Use nitrogen and irrigation judiciously.
- Use yellow sticky traps at 12/ha to attract and kill insects.
- Apply carbofuran 3% G @ 40 kg /ha or spray any one of the following insecticides
- Pesticide- Carbofuran 3 CG40 kg/ha, Dimethoate 30 % EC1.0 ml/lit, Malathion 50 % EC1.5 ml/ lit, Methl demeton 25 EC1.0 ml/ lit, Cyantraniliprole 10.26 OD1.8ml/lit, Imidacloprid 17.8 SL3.0ml/10lit, Spiromesifen 22.9 SC1.25ml/lit.

Thrips, *Thrips tabaci, F. rankliniella* (Thiripidae; Thysanoptera)

Distribution: Bangladesh, India, Indonesia, Japan, Malaysia, Sri Lanka

Host: Groundnut, Rice, Green gram

Symptoms of damage:

- Silvery streaks on leaf surface
- Pre-mature dropping of flowers
- Bud necrosis.
- Vector of tomato spotted wilt virus.

Identification of pest:

Nymphs: Yellowish

Adult: Dark coloured with fringed wings

Management:

- Cyantraniliprole 10.26 OD 1.8ml/lit.
- Spiromesifen 22.9 SC 1.25ml/lit
- Mechanically uproot the infected plants and destroy them
- Use yellow sticky traps @ 15/ha
- Release larvae of Chrysoperla cornea @10,000/ha
- Spray methyl demeton 25 EC @1lit/ha or dimethoate 30 EC @1lit/ha

Striped mealybug, *Ferrisia virgate* (Pseudococcidae; Hemiptera)

Distribution: Eastern Africa and South America

Host: Cotton, Guava

Symptoms of damage:

- Presence of white, cottony mealy bugs on the leaves and twigs
- Stunted growth

Identification of pest:

- Crawler: Yellowish to pale white in colour
- Adult: Females apterous, long, slender covered with white waxy secretion

Management:

- Spray FORS 25g/lit or neem oil 0.5% along with teepol 1 ml/lit
- Spray any following insecticides
- Phosphomidon 40 SL 2ml/lit
- Imidacloprid 80.5 SC 0.6 ml/lit
- Thiamethoxam 25 WSG 0.6 mg/lit

Red spider mite, *Tetranychus spp* (Tetranychidae; Acarina)

Distribution: Africa, Pakistan, Middle East, Sri Lanka, South East Asia, USA and Japan.

Host: Coconut, Red gram

Symptoms of damage:

- Affected leaves become reddish brown and bronzy
- Severe infestation larvae silken webbing on the leaves, wither and dry
- Flower and fruit formation affected

Identification of pest:

- Eggs: Hyaline, globular laid in mass
- Nymphs: Yellowish in colour
- Adult: Red coloured small sized

Management:

- Avoid monoculture
- Spray wettable sulphur 50 WP 2g/lit or dicofol 18.5 EC 2.5 ml/lit

Pinworm, *Tuta absoluta* (Gelechiidae; Lepidoptera)

Distribution: United States, Western Europe.

Host: Green gram

Symptoms of damage:

- Mining of leaves, stem and Pinholes on fruits

Management:

- Collect and destroy the pinworm affected plants and fruits
- Avoid solanaceous crops after tomato
- Use healthy seedlings for transplanting
- Keep pheromone traps @ 16 nos./ac
- Spray Chlorantraniliprole 18.5% SC @ 60 ml
- Neem formulation (Azadirachtin 1%) @ 400 – 600 ml/ac

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VACUUM PACKAGING

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Introduction

Vacuum packaging is a method of packaging where air from the interior of a package is removed in its entirety immediately prior to sealing the package. This involves placing food products in a plastic film package (or potentially a film package made with other polymer materials), removing air from inside the package with a vacuum pump, and then sealing the package (Church & Parsons, 1995). The materials used for vacuum packaging must be strong enough to withstand the vacuum, flexible enough to form around the food product, and have a very specific level of heat sensitivity. Regarding the heat sensitivity of the material, the material must be sealed during the packaging process, but also suitable for moderate temperatures during cooking (e.g., 75°C). This is especially the situation with the emerging popularity of sous vide cooking of foods.

Vacuum packaging was invented in the 1950s by a German inventor named Karl Busch, who used the discovery for vacuum packaging meat products. Today, vacuum packaging is common for long duration storage of dry foods like cereals, nuts, cured meats, cheese, and smoked fish, as well as short duration storage of fresh foods like vegetables, meats, and liquids. Vacuum packaging of foods offers several distinct advantages for the food industry, mainly associated with the reduction, or even the potential elimination, of atmospheric oxygen. This slows the rate of oxidative reactions (i.e., lipid oxidation and protein oxidation) and limits the growth of aerobic bacteria and fungi.

There are several challenges with the implementation and use of vacuum packaging in the food industry. The first challenge is associated with consumer perception of some food products. For example, consumers of meat products are accustomed to specific color cues of meat products (e.g., fresh beef is characteristically red when exposed to oxygen or stored in an aerobic environment); however, an anaerobic environment causes a change in the chemical state of the protein myoglobin, which causes temporary undesirable color cues for meat products (e.g., fresh beef appears dark red or purple in an anerobic environment) (Suman & Joseph, 2013). Another significant challenge with vacuum packaging is the requirement of synthetic packaging materials (i.e., plastic), as very few biodegradable and bio-based packaging materials are capable of meeting the aforementioned technical requirements to undergo vacuum packaging.

Important properties by which consumers judge fish and shell fish products are appearance, texture and flavour. Appearance, specifically colour, is an important quality attribute influencing the consumer‘s decision to purchase. In fresh red meat fishes, myoglobin can exist in one of three chemical forms. Deoxymyoglobin, which is purple, is rapidly oxygenated to cherry red oxymyoglobin on exposure to air. Over time, oxymyoglobin is oxidised to metmyoglobin which results in a brown discoloration associated with a lack of freshness. Low oxygen concentrations favour oxidation of oxymyoglobin to metmyoglobin. Therefore, in order to minimize metmyoglobin formation in fresh red meats, oxygen must be excluded from the packaging environment to below 0.05% or present at saturating levels. Lipid oxidation is another major quality deteriorative process in muscle foods resulting in a variety of breakdown products which produce undesirable off-odours and flavours. Hence O2 may cause off-flavours (e.g. rancidity as a result of lipid oxidation), colour changes (e.g. discolouration of pigments such as carotenoids, oxidation), nutrient losses (e.g. oxidation of vitamin E, β- carotene, ascorbic acid) and accelerates microbial spoilage thereby causing significant reduction in the shelf life of foods.

Therefore, control of oxygen levels in food package is important to limit the rate of such deteriorative and spoilage reactions in foods. Oxygen level in the package can be controlled by using the vacuum packaging technique in which, the air present in the pack is completely evacuated by applying vacuum and then package is sealed. Vacuum packaging, which is also referred as skin packaging involves removal of air inside the pack completely and maintaining food material under vacuum conditions, so that oxygen available for the growth of microbes and oxidation will be limited. This will help in doubling the shelf life of fish under chilled conditions.

This technique is particularly useful in fatty fishes, where the development of undesirable odour due to the oxidation of fat is the major problem. Vacuum packaging for chilled and refrigerated fishes doubles the shelf life compared to normal air packaging. Application of this to frozen fishes is also commonly followed as it helps in reducing problem of freezer burn. This technique can be applied to fresh meat and fishes, processed meat and fishes, cheese, coffee, cut vegetables etc. One of the important aspect in the vacuum packaging is the use of packaging material with good barrier properties. Normally polyester-polyethylene or nylon-polyethylene laminates are used. Polyester and nylon provides good strength and acts as good barrier to oxygen. Polyethylene proves good heat sealing property and is resistant to water transmission. Typical vacuum packaging machine and vacuum packed fish is shown in Fig1.



Vacuum packaging machine

Packaging materials

In order to maintain a vacuum around the food, high O_2 barrier materials and high levels of seal integrity are required. Although the requisite O_2 barrier for vacuum packaging depends on the type of food packaged, O_2 transmission rates of less than 15 $cm^3\ m^{-2}\ day^{-1}\ atm^{-1}$ are generally required. Also, packaging materials with low WVTRs must be used. Typical vacuum packaging materials consist of coextruded or laminated films such as OPP/EVOH/PE, PA/PE, PET/PE, OPP/PVDC/PE, OPP/PVDC/OPP and PVC/EVOH/PVC

Advantages of Vacuum packaging

- Reduces fat oxidation
- Reduces growth of aerobic microorganisms
- Reduces evaporation
- Reduces weight loss
- Reduces dryness of product
- Reduces freezer burn
- Reduces volume for bulk packs Eg. Tea powder, dry leaves etc
- Extends the shelf life
- Easy to use and maintain the equipment Disadvantages of Vacuum packaging
- Cannot be used for crispy products and products with sharp edges
- Requires high barrier packaging material to maintain vacuum
- Creates anaerobic condition, which may trigger the growth and toxin production of Additional barriers / hurdles are needed to control these microorganisms.

Methods for vacuum packaging meats

1. Shrink bag method
2. Non-shrink bag method
3. Thermoforming method
4. Vacuum skin packaging

Shrink bag method

This system involves placing the meat into a heat shrinkable barrier bag (typically a triple-layer co-extruded films constructed from EVA copolymer-PVdC copolymer-EVA copolymer, but sometimes PA is used the barrier layer with an ionomer as the inner or outer layer). The bag is then evacuated prior to sealing. In the past, this was achieved by applying a metal clip around the twisted neck of the bag, but today, heated jaws are used. The bag is then heat shrunk by placing in water at 90˚C. After shrinking, the bag conforms closely to the meat and produces a tight vacuum pack. Very high vacuum levels are achieved on rotary single-chamber machines, which also heat seal shrink bags and owing to their improved productivity and versatility, these machines have become the industry standard. Large primal cuts up to 205 mm deep and 460 mm wide can be vacuum packaged using this type of equipment.

Non-shrink Bag Method

In this technique, meat is placed into a preformed plastic bag, which is then put in an enclosed chamber that is evacuated. When a predetermined low pressure has been reached, heated jaws close and weld the mouth of the bag. Typical bag constructions consists of laminates or co-extrusions, which include PET as the outside layer to provide strength, PA as the middle layer to provide a good O_2 barrier, and inner layers of LDPE, ionomer or EVA copolymer, which are good moisture barriers and can be easily heat sealed. A typical structure would be ionomer-PA-EVA copolymer. Because the bags used in this system are not heat shrinkable, purge tends to accumulate in corners during storage. Secondary sealing (also referred to as self-welding) has been introduced to overcome this problem, and involves passing the vacuum packs through a heating tunnel. Because of the ease with which these films are heat sealed, the excess area of film around the meat is sealed. If performed perfectly, then the packaging material size can be reduced or sealed to a point that approximates the surface area of the meat inside. This prevents purge from spreading into the film wrinkles, folds and corners as well as providing a wider heat seal, which reportedly reduces the incidence of leaking bags.

Thermoforming method

In this method, deep trays are thermoformed in-line from a base web of plastic. Meat is placed in the trays and an upper web of plastic is heat sealed under vacuum to form a lid. Generally, the materials used for thermoforming are laminates of PA, PET or PVC, sometimes with a PVdC copolymer coating and heat sealing layers such as LDPE, EVA copolymer or ionomer.

Thermoforming Films are sometimes referred to as :

Thermoforming film, form film, seal film, high barrier film, top and base film, rpet film, apet film, PVC/PE, PVS, flexible film, food packaging film, toplex film, semi rigid film, film thermoforming, thermoformable packaging, rigid film, boilable film, vac pac, meat packaging film.

Vacuum skin packaging

Vacuum skin packaging (VSP) involves production of a skin package in which the product is the forming mold. It was first introduced using an ionomer film, which softens on heating to such an extent that it can be draped over sharp objects without puncturing. In this technique, meat portions are skin packed in a barrier film material, the top of which is softened

by heating before applying a vacuum and sealing. During this operation, the soft films molds itself to the shape of the meat to give a skintight packaging, the meat thus being held under anaerobic conditions. It forms closely around the meat and seals to the base film.

In comparison with MAP meat, it was found that VSP meat remained acceptable microbiologically for up to at least 2 weeks after packing, during which time the colour, although not red, was unchanged. However, the meat retained its ability to develop a bright red colour when exposed to air for at least 2 weeks during storage at 1˚C. As is typical for vacuum-packaged meat, lactic acid bacteria predominated on VSP samples on which spoilage bacteria grow slowly, if at all, resulting in a long, odour-free shelf-life. Off-odours developed much more rapidly in MAP packs than in VSP. In choosing between MAP and VSP it was concluded that the retailer must balance the attractive red colour achieved over a relatively short period by MAP against the longer-term stability (albeit with an unaccustomed purple meat colour) afforded by VSP.

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UPLIFTMENT OF RURAL FAMILY INCOME THROUGH ENHANCED CROPPING INTENSITY IN RICE FALLOW

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Introduction

Cropping intensity is one of the viable options left to enhanced rural family income. Cereals, mostly rice are the most important crop grown in Churachandpur district, Manipur. The agriculture in the district is mono-cropped keeping the lands mostly fallow after rice except in few pockets where the irrigation facilities are available. Non availability of irrigation is a major constraint in adoption of *rabi* crops in the region. Traditionally, the tillage practice of rapeseed showed that there were over 3 ploughings with the tractor/power tiller. As mustard is the most common source of edible oil in this country which ranks top among the oil seed crops (Chowhan and Islam, 2021) the zero-tillage technology is becoming a savior to the farmers where farmers are mostly risk averters due to variations of weather and other climatic conditions. For a technology to be adopted and really effective, it is a pre-requisite that it has been evaluated with respect to its economic feasibility and viability which is a major determinant of its adoption. Zero tillage (ZT) technology in mustard variety TS-38 allows farmers to plant 15 days earlier than usual after rice crop.

Since the cost of land preparation is zero the technology is becoming a savior to the farmers of the state which also generates higher net income. This approach also reduced weed problems – due to less disturbance of soil under zero tillage, fewer weed seeds are exposed and fewer germinate. Since there was no rain throughout the crop period, the growth and yield parameters in all the rapeseed-mustard varieties were better in zero tillage than conventional

tillage due to residual soil moisture after rice harvest. Zero tillage is one of the most used RCTs (Gupta, 2007) employed for saving precious resources, which gives more economic production (Hobbs, *et al*., 2002), lower production cost and saving in water and energy (Reifschneider, 2007). Zero tillage not only promotes input-use efficiency but also strengthens natural resource base (Laxmi and Mishra, 2007).

On the other hand, minimum tillage has numerous positive effects on soil, such as improvement of water content, reduction of soil erosion and fuel economy, but minimum tillage can also lead to soil compaction, which could affect seed germination, root growth and crop yield (D'Haene *et al*., 2008). It is essential to sustain increased production besides nutritional standard of people Therefore, cultivation of these *rabi* crops involve intensive cultural operations starting from sowing to marketing, it provides more and regular employment opportunities in rural areas.

Cropping system

The study was conducted at Churachandpur district, Manipur under the supervision of ICAR-KVK Churachandpur. The cultivation of mustard TS-38 after *kharif* rice fallow under zero tillage-a resource conservation technology was taken up at four villages in cluster mode during *rabi* 2024-25. Residual soil moisture (after rice) was utilized to germinate the mustard seeds. The zero-tillage technology of mustard (TS-38) and pea (Kashi Mukti) in system approach after rice crop leads to the transformation of the monocropped rice cropping system to doubled cropped rice-rapeseed and rice-pea cropping system. Soil moisture remains limited in the region during dry season occurring almost no rainfall. Besides, the other *rabi* crop pea (Kashi Mukti), was also cultivated under minimum tillage system approach after rice to generate higher net income. Most of the farmers kept fallow land after rice except some farmers growing vegetable pea where irrigation facilities are available in conventional tillage practices which implies higher energy input resulting in lower input use efficiency. Conservation practices have shown advantages over traditional practices by adopting minimum tillage technique by improving productivity and soil health. Therefore, a slight opening is made on soil surface for placing the pea seed.

All the agronomic practices were strictly followed. Fertility management includes applications of N, P and K. Nitrogen applications are split between planting side dressing. Total N applied is determined by cropping history and according to crop grown. Mustards were harvested when 75% of the siliquae became golden colour. It is important to schedule a complete

harvest so that maximum yield and quantity are attained. Finally, the yield data of different crops were recorded at the time of harvest and converted into average tones/ha.

Outcome and Impact:

It is evident from Table 1 that the cultivation of high yielding mustard variety TS-38 taken up in rice fallow under zero tillage-a resource conservation technology yielded to 0.72 t/ha. Similar trend was also observed when the returns rupees invested was concerned, the crop gave impressive net returns of Rs. 16,550/- with BC: Ratio of 1.8 respectively. It might be due to low cost of production and better yield production. Zero tillage technology is very conductive in increasing the rapeseed production and net income; its popularity increased among the farming community. Extension activities should be strengthened among households through technical support and front line demonstration (FLDs). (N. Prakash and S.B. Singh 2010). As in many rural development programmes, the government assistance appears to have a substantial impact on the adoption of zero tillage technology, the finding constant with survey by Pattanayak and Mercer (1998).

On the other hand, vegetable pea variety Kashi Mukti attained the yield of 6.6 t/ha under minimum tillage practice. Perusal data in Table 1 also revealed that the net returns was observed maximum in pea obtaining Rs. 1,04,350 with BC: Ratio of 2.7 respectively.

Table 1. Economics of mustard and pea under RCT during *rabi* 2024-25

Crop	Variety	Yield (t/ha)	Economics (Rs.ha)			
			Gross Cost	Gross Return	Net Income	BCR
Rapeseed	TS-38	0.72	19,450	36,000	16,550	1.8
Pea	Kashi Mukti	6.6	60,650	1,65,000	1,04,350	2.7

Note: *Selling price of rapeseed @ Rs. 50 and Selling price of pea @ Rs. 25.*



Fig.1 Zero tillage cultivation of mustard TS-38



Fig. 2 Minimum tillage cultivation of pea var. Kashi Mukti

Conclusion

The present field study indicates that mustard is a climate resilient crop which can be grown in the residual soil moisture. By adopting zero tillage, the farmers could increase the productivity, reduced cost of cultivation, increased the cropping intensity and earned an additional income with less effort. Zero tillage also helps in timely sowing (October-November), conserves soil moisture and requires less water, saves tillage cost and time protecting soil from erosion due to the retention of surface residues and reduce organic matter depletion. Besides pea being a leguminous crop improves the soil health. Therefore, the study concluded that zero and minimum tillage under rapeseed and pea with high yielding variety is highly remunerative due to its economic viability leading to economic improvement and empowerment of farmers respectively. The adoption of these technologies may be encouraged which eventually contribute towards reducing poverty and keeping environment clean.

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MAGNETOPONICS: REDEFINING AGRICULTURE AND FARMING THROUGH LEVITATING SEEDS

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Introduction

Magnetoponics in agriculture refers to the application of magnetic fields to enhance various aspects of plant growth and crop production. It is an emerging field of agricultural technology that combines hydroponics (soilless cultivation) with the application of magnetic fields to enhance plant growth, nutrient uptake, and productivity. It involves exposing nutrient solutions or plant systems to static or dynamic magnetic fields, which are believed to influence biochemical and physiological processes in plants. The basic idea is that magnetic fields can alter the properties of water and nutrient solutions, such as surface tension, viscosity, and ion mobility, leading to improved nutrient absorption by plant roots. Magnetoponics was first performed by the Dutch researchers in the high-tech greenhouse of Netherlands using magnetic levitation to grow crops without soil. Seeds enveloped in diamagnetic coatings are levitated within electromagnetic chambers, where they are cultivated in vertically arranged layers under meticulously regulated conditions of light and nutrient delivery. Magnetoponics represents a novel approach to food production that has the potential to enhance environmental sustainability, improve resource-use efficiency, and promote cleaner agricultural practices. Unlike conventional hydroponic or aeroponic systems, this innovative approach floats seeds in a nutrient-enriched mist without the use of containers, substrates, or root support structures. The complete elimination of soil mitigates risks associated with compaction, erosion, and contamination. Powered by renewable energy sources, the system integrates intelligent control mechanisms to dynamically adjust lighting and nutrient mist according to the specific developmental stage of

each plant. This cultivation method has the potential to support food production for growing populations without reliance on fertile soil or expansive arable land. By reducing the dependency on traditional farmland, it offers a sustainable solution to the increasing pressure on Earth's limited agricultural resources. This advanced cultivation technique holds significant potential for revolutionizing urban agriculture, sustainable greenhouse operations, and extraterrestrial crop production by providing a soil-free, waste-minimizing, and low-stress environment for plant growth.

How it works?

1. Magnetized Water: Water or nutrient solutions are passed through magnetic devices, which reorganize water molecules and potentially enhance solubility and mobility of nutrients.

2. Magnetic Exposure: Either the plant, the growing system, or the solution is exposed to magnetic fields of specific strengths and durations (usually measured in milliTesla, mT).

3. Controlled Systems: Magnetoponics is mostly explored in controlled environments like greenhouses, growth chambers, and hydroponic setups.



Magnetic Water Treatment (MWT) is one of the most common applications. The theory suggests that passing irrigation water through a magnetic field alters its physical properties. Restructure of

water molecules by forming smaller, more organized clusters (e.g., hexagonal structures) that can more easily penetrate plant cell membranes, leading to better water and nutrient uptake. Making water more "wettable" and improving its absorption by soil and plants helps to reduce surface tension. Applying static or pulsed magnetic fields directly to seeds, seedlings, or plants helps in direct contact with magnetic force. This is thought to influence enzyme activity and biochemical processes. Magnetic fields might affect the orientation and movement of charged particles within plant cells, potentially influencing metabolic pathways, hormone production, and nutrient transport. It enhances cell division and elongation leading to faster growth. By impacting chlorophyll production and the efficiency of light energy absorption, it improves photosynthetic efficiency.

Applications in Agriculture

Vegetable production especially leafy greens like tomato, lettuce, spinach, and herbs can be done through this technique. Magnetically treated nutrient solutions have shown to increase biomass and fruit yield. It can be sued in Controlled Environment Agriculture (CEA) such as greenhouses and vertical farms. Magnetic seed priming improved germination in maize, soybean, and wheat. Magnetic water alleviated the effects of salt stress in hydroponically grown crops. Early experiments conducted under controlled greenhouse conditions demonstrate that seeds cultivated using this method exhibit accelerated growth, reduced incidence of disease, and enhanced root system development. Preliminary findings suggest that germination rates are approximately 25% higher compared to conventional planting techniques, indicating a significant improvement in early plant establishment and vigor.

Reported benefits of Magnetoponics

Numerous studies have reported positive effects of magnetic field applications in agriculture, including:

Enhanced seed germination and seedling vigor: Magnetic treatment of seeds can improve germination rates, speed of emergence, and initial seedling growth.

Improved root development: Roots grow deeper and denser, increasing nutrient absorption efficiency.

Increased crop yield and quality: Higher biomass, improved fruit quality, and increased yields have been observed in various crops.

Improved water and nutrient uptake: Magnetized water is believed to facilitate better absorption of water and dissolved nutrients by plants, potentially leading to increased water use efficiency.

Increased photosynthetic pigment content: Leading to more efficient photosynthesis.

Enhanced plant resilience: Some studies suggest that magnetic fields can improve a plant's resistance to diseases, pests, and environmental stresses like drought.

Reduced chemical use: By promoting healthier plant growth, magnetoponics might reduce the need for certain agrochemicals.

Stress tolerance: Magnetoponics can help plants better withstand salinity, drought, and heavy metal stress.

Early experiments indicate that suspending seeds in air significantly reduces the incidence of fungal diseases, which are commonly associated with waterlogged soil or overcrowded seedling trays. When roots are exposed to an open environment with unrestricted airflow, oxygen availability increases, thereby minimizing plant stress. This aerated root zone, inherent to magnetoponics systems, not only promotes healthier growth but also reduces the dependence on chemical fungicides and soil sterilization treatments.

Challenges of magnetoponics

Magnetic field strength, duration, and exposure methods vary widely across studies, so it lacks standardization. Though promising, more peer-reviewed studies are needed for conclusive evidence and scientific validation. Magnetic treatment equipment may be costly or not easily available to all farmers.

Conclusion

Magnetoponics offers an intriguing, environmentally friendly approach to improving agricultural productivity. It holds great promise for sustainable, high-efficiency agriculture, especially in urban farming and resource-constrained environments. As research progresses, it has the potential to contribute to more sustainable and efficient food production systems. It's important to note that while many studies show positive results, the effectiveness can vary depending on the plant species, magnetic field parameters, and environmental conditions. More rigorous and large-scale studies are needed to fully validate the claims and establish magnetoponics as a mainstream agricultural practice.

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FUTURE-PROOF PEST MANAGEMENT: NEXT-GEN MICROBIAL AND BOTANICAL BIOPESTICIDES

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Abstract

The growing challenges of pesticide resistance, environmental contamination, and food safety concerns have accelerated the quest for sustainable pest management alternatives. Next-generation biopesticides, particularly those derived from microbial agents and botanical extracts, offer promising solutions. Recent advancements include novel strains of entomopathogenic fungi, bacteria, and viruses with enhanced pathogenicity, as well as plant-based compounds formulated using nanotechnology and microencapsulation to improve stability and efficacy. These innovations ensure targeted action against insect pests while minimizing impacts on non-target organisms and ecosystems. Moreover, integrating these biopesticides into integrated pest management (IPM) programs can delay resistance development and reduce chemical pesticide residues. This article highlights key developments in microbial and botanical insecticides, their mechanisms, and their potential to transform pest management practices. Embracing these eco-friendly tools is essential for achieving resilient agricultural systems, safeguarding biodiversity, and meeting global demands for safe and sustainable food production.

Key Words

Biopesticides, microbial insecticides, botanical insecticides, entomopathogens, sustainable agriculture, integrated pest management, pest resistance management, plant extracts, eco-friendly pest control, nanotechnology formulations.

Introduction

Modern agriculture faces mounting challenges from insect pests that threaten crop yields and quality. Conventional chemical pesticides, though effective, have led to widespread issues such as pest resistance, resurgence, non-target impacts, and environmental contamination. This necessitates safer alternatives that align with sustainable agriculture goals.

Biopesticides, derived from natural sources including microbes and plants, offer specific, biodegradable, and environmentally compatible solutions. Recent innovations in biotechnology, strain improvement, and formulation science have paved the way for next-generation microbial and botanical insecticides with enhanced efficacy and stability. This article explores these cutting-edge developments, highlighting their significance in modern pest management.

Table 1 : Examples Of Microbial & Botanical Biopesticides

S. No	Biopesticide Name	Source/Organism	Target Pests / Use
1	*Bacillus thuringiensis (Bt)*	Bacterium	Caterpillars, beetles, mosquitoes
2	*Beauveria bassiana*	Entomopathogenic fungus	Whiteflies, aphids, thrips
3	*Metarhizium anisopliae*	Entomopathogenic fungus	Grasshoppers, termites, soil insects
4	*Trichoderma harzianum*	Fungus	Plant pathogenic fungi (soil diseases)
5	Nucleopolyhedrovirus (NPV)	Virus	Caterpillars (Helicoverpa, Spodoptera)
6	Neem oil / Azadirachtin	Extract of Azadirachta indica	Wide range of insects; antifeedant & repellent
7	Pyrethrin	Extract of Chrysanthemum flowers	Mosquitoes, flies, moths
8	Rotenone	Extract from Derris roots	Beetles, aphids, leaf-eating insects
9	Garlic extract	Allium sativum	Aphids, caterpillars (repellent action)
10	Ryania	Extract from Ryania speciosa stems	Caterpillars (fruit borers)

Source : Directorate of Plant Protection, Quarantine & Storage. (n.d.). Registered biopesticides. ICAR-PPQS, India. Retrieved June 30, 2025, from https://ppqs.gov.in

Advances in Microbial Insecticides

1.Enhanced Entomopathogenic Bacteria

a)Novel Bt Strains and Genes

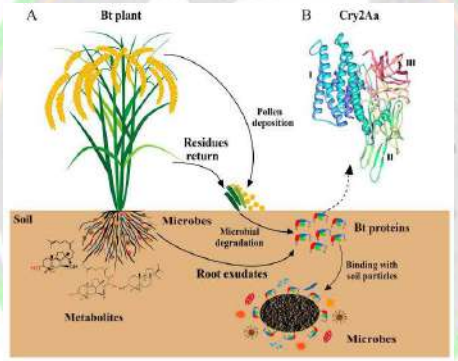
The most widely used microbial biopesticide is *Bacillus thuringiensis* (Bt), a spore-forming bacterium that produces crystal (Cry) and cytolytic (Cyt) proteins toxic to insect larvae. While Bt has been successful against caterpillars (Lepidoptera), beetles (Coleoptera), and mosquitoes (Diptera), pest populations have started developing resistance.

To counter this, next-generation Bt products include:

New strains with multiple Cry genes targeting different receptors in insect midguts, reducing chances of resistance.

Molecularly engineered Bt strains expressing hybrid or chimeric toxins.

Formulations combining Bt with gut flora modulators to enhance insect mortality.



Behaviour of *Bacillus thuringiensis* Source : https://www.mdpi.com

b)Improved Formulations

Modern Bt formulations incorporate UV-protectants, phagostimulants (to encourage larvae to feed), and encapsulating agents to extend field persistence.

2. Entomopathogenic Fungi: Genetic and Formulation Innovations

a)Key Fungal Agents

Fungi such as *Beauveria bassiana, Metarhizium anisopliae, Isaria fumosorosea, and Verticillium lecanii* infect insects through their cuticle, making them effective even against piercing-sucking pests like aphids, whiteflies, and thrips.

b)Genetic Improvements

Scientists are selecting or engineering strains with enhanced virulence, faster sporulation, or tolerance to UV and high temperatures.

Some next-gen strains produce higher levels of destruxins and beauvericin, secondary metabolites that contribute to insect mortality.

c)Oil-based and Granular Formulations

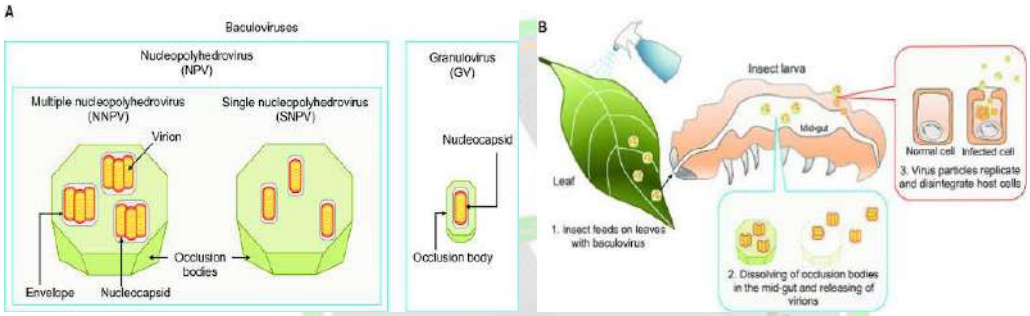
New oil-based formulations allow spores to adhere better to insect cuticles and resist environmental stress. Granular carriers help target soil-dwelling pests like grubs and termites.

3.Viral Biopesticides: NPVs and GVs

a) Baculoviruses

Nucleopolyhedroviruses (NPVs) and Granuloviruses (GVs) are highly specific to certain insect pests, such as *Helicoverpa armigera, Spodoptera litura,* and *Plutella xylostella.*

Infection Cycle Of Baculoviruses



Source : https://www.researchgate.net/figure

b)Innovations

Modern formulations include UV-blockers like optical brighteners (stilbene derivatives) which protect viral occlusion bodies.

Genetic engineering focuses on inserting insect-specific enhancin genes to disrupt gut barriers and increase speed of kill.

4.RNAi-Based Microbial Products

Recent breakthroughs involve engineering bacteria and fungi to produce double-stranded RNA (dsRNA) targeting essential genes in pests. Ingested dsRNA triggers RNA interference, silencing these genes and disrupting development.

Examples include:

RNAi constructs targeting genes involved in molting or digestion.

Co-delivery with entomopathogenic fungi to increase uptake.

Innovations in Botanical Insecticides

1.New Plant Sources and Active Compounds

a)Beyond Neem

While neem-based products (azadirachtin) remain widely used, research is identifying new botanical sources such as:

Custard apple seeds (*Annona spp*.): Rich in acetogenins with insecticidal and antifeedant activity.

Turmeric (*Curcuma longa*): Contains curcuminoids that disrupt insect hormonal balance.

Garlic extracts: Sulfur compounds interfere with insect nervous systems.

Essential oils from lemongrass, eucalyptus, and rosemary: Effective as repellents and oviposition deterrents.

b)Pure Phytochemicals

Isolation of active compounds like rotenone, pyrethrins, alkaloids (nicotine), flavonoids, and terpenoids enables more precise applications and standardized doses.

2. Synergistic Botanical Blends

Combining plant extracts with different modes of action or mixing botanicals with microbial agents can provide superior control.

For example:

Neem oil plus Bt enhances larval mortality in *Helicoverpa*.

Essential oil mixes repel adult insects while microbes target larvae.

3. Nano and Smart Formulations

Botanical actives often degrade rapidly under UV and rainfall. Innovations include:

Nanoemulsions: Improve dispersion, adhesion on leaf surfaces, and penetration into insect cuticle.

Polymer encapsulation: Controls release, allowing prolonged protection.

Silica or clay nanoparticles: Increase stability and reduce volatilization.

III. Formulation and Application Innovations

1. Microencapsulation for Controlled Release

Microencapsulation uses polymers like alginate, gelatin, or chitosan to coat microbial spores or plant compounds. This protects actives from sunlight and desiccation, and ensures a slow, sustained release.

2. Adjuvants, UV Protectants, and Stickers

Formulations now incorporate additives that:

Enhance adhesion on waxy leaf surfaces.

Reduce wash-off by rain.

Block harmful UV rays to extend field longevity.

3. Precision Application Tools

Advances in drone spraying, electrostatic sprayers, and low-volume applicators allow uniform distribution of biopesticides, reducing wastage and improving efficacy.

IV. Integration into IPM and Benefits

1. Managing Resistance

Using biopesticides with novel modes of action interrupts pest adaptation cycles. Strategies include:

Rotation: Alternating biopesticides with chemical insecticides.Mixtures: Combining microbials with botanicals to achieve multiple attacks on pests.

2. Conserving Natural Enemies

Unlike broad-spectrum chemicals, most biopesticides are safe for predators, parasitoids, and pollinators. This preserves ecological balance and enhances natural biological control.

3. Reduced Chemical Residues

Biopesticides degrade rapidly into harmless products, leaving minimal residues. This aligns with international standards for export and consumer food safety.

4. Supporting Organic and Climate-Smart Farming

Biopesticides are approved under organic certification schemes and align with climate-resilient agriculture by lowering chemical footprints and promoting soil health.

Conclusion

Next-generation biopesticides, driven by innovations in microbial strains, plant-derived compounds, smart formulations, and genetic technologies, represent a sustainable frontier in pest management. They not only address the urgent issues of pesticide resistance and environmental contamination but also complement integrated pest management systems by conserving beneficial organisms and reducing chemical residues. Continued investments in research, farmer education, and regulatory support are essential to harness their full potential. By embracing these eco-friendly tools, agriculture can advance towards resilient, productive, and environmentally safe food systems.

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BAMBOO WASTE VERMICOMPOSTING

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Introduction

Vermicomposting is an agricultural recycling process for biodegradable solid waste that is facilitated by the decomposition and digestion of earthworms and associated microorganisms. The feedstocks that are commonly used for vermicomposting include animal manure and vegetable or fruit scraps from kitchens or farms. Many kinds of vermicompost are known to be used as a component of nursery potting media sowing to their ability to control plant pathogens such as *Pythium ultimum Trow var. ultimum, Rhizoctonia solani Kuhn, and Verticillium sp.* Vermicompost water extract is generally at 1: 10 or 1: 20 dilution ratio of vermicompost to water aerated over a certain period of time, pending on usage, for the purpose of numerous bioactive molecules as well as microbial populations of the vermicompost. Applying vermicompost water extract to crops is easier than applying vermicompost, which is bulky and heavier, and needs soil incorporation that makes post-plant treatment impractical in many cases. Many scientists reported that drenching vermicompost water extract suppressed plant-parasitic fungi, or plant-parasitic nematodes such as *Meloidogyne spp*. in different crops. Thus, vermicompost can be used in either solid or liquid. *Rhizoctonia solani* and *Pythium spp*.

Bamboo in India

Bamboo is a versatile and highly valued plant in India, known for its ecological, economic, and cultural significance. India is home to a rich diversity of bamboo species, with over 136 species found across the country.

Area Occupied by Bamboo in India

- **Bamboo Cover:** India has a bamboo cover of approximately 13.96 million hectares, accounting for about 12.96% of the country's total forest cover.

- **Distribution:** Bamboo is widely distributed across various states in India, including the northeastern states, Chhattisgarh, Odisha, and the Western Ghats.
- **Importance:** Bamboo plays a vital role in the lives of millions of people in India, providing livelihoods, food, shelter, and other essential products.

It was found that, approximately 11.25 tons of bamboo leaf wastes will be obtained from the one hectare of bamboo forests. Bamboo leaf wastes consist of 19.5-26.3% cellulose, 11.30-13.50% hemi cellulose and 8.7-11.60 % lignin. It also contains 34.6-37.5% organic carbon.

Preparation

Step 1: Mix the bamboo leaf wastes and cow dung in the ratio of 5:1 and add microbial consortia (@ 2 kg/ton) and allow it for partial composting.

Step 2: Then release the earthworms into the compost pit (*Eudrilla euginea*) @ 3 kg/ ton and keep it for 75 days.

Step 3: Finally the vermicompost was prepared after 75 days of composting.

Bamboo Species used in Vermicomposting

Various bamboo species can be used for vermicomposting, and the suitability may depend on factors like leaf composition and nutrient content. Some commonly used bamboo species include:

- *Bambusa bambos*: A widely distributed bamboo species with leaves that can be used for vermicomposting.
- *Dendrocalamus giganteus*: A giant bamboo species with leaves that can be utilized for vermicomposting.
- *Bambusa tulda*: A bamboo species with leaves that can be used for vermicomposting, potentially providing nutrients for plant growth.



Bambusa bambos



Dendrocalamus giganteus



Bambusa tulda

The specific bamboo species used may influence the nutrient content and quality of the vermicompost produced. Research on bamboo leaf vermicomposting often focuses on optimizing

the composting process and exploring the benefits of using bamboo leaves as a nutrient-rich organic amendment.

Earthworm Species Used in Bamboo waste Vermicomposting

Vermicomposting, or worm composting, utilizes specific earthworm species to break down organic matter, including bamboo leaves. Some commonly used earthworm species for vermicomposting are:

- ✓ *Eisenia fetida*: A popular species for vermicomposting due to its tolerance of a wide range of environmental conditions and its ability to consume a variety of organic materials.
- ✓ *Eisenia andrei*: Similar to *Eisenia fetida*, this species is also well-suited for vermicomposting and can thrive on a diet of bamboo leaves and other organic matter.
- ✓ *Perionyx excavatus*: A tropical earthworm species often used in vermicomposting, particularly in Asia. It is known for its high waste consumption rate and ability to tolerate a variety of organic materials.



Eisenia fetida



Eisenia andrei



Perionyx excavatus

Effect of Bamboo leaf vermicompost on problematic soil

Effect on Soil Physical Properties

- ➢ Improved Aggregate Stability: Vermicompost can increase soil aggregate stability, reducing soil erosion and runoff.
- ➢ Reduced Bulk Density: Vermicompost can decrease soil bulk density, making it easier for roots to grow and improving water infiltration.
- ➢ Increased Water Holding Capacity: Vermicompost can improve soil's water-holding capacity, reducing the need for frequent watering.

Effect on Soil Chemical Properties

- ▪ Increased Nutrient Availability: Vermicompost can increase the availability of nutrients such as nitrogen, phosphorus, and potassium, promoting plant growth.

- pH Regulation: Vermicompost can help regulate soil pH, potentially mitigating the negative effects of acidic or alkaline soils on plant growth.

Effect on Soil Biological Properties

- Increased Microbial Biomass: Vermicompost can increase soil microbial biomass and activity, promoting soil health and fertility.
- Improved Enzyme Activity: Vermicompost can enhance enzyme activity related to carbon, nitrogen, and phosphorus cycling, supporting nutrient availability.

Problematic Soil Remediation

- Heavy Metal Reduction: Bamboo compost has been shown to reduce heavy metal pollution in soil, making it a potential bioremediation agent.
- Soil Health Improvement: Vermicompost can improve soil health, fertility, and structure, making it more conducive to plant growth.

Effect of biochar addition of bamboo waste vermicomposting

The effect of bamboo biochar addition (at 0%, 3%, and 6% on a dry w/w basis) on the activity of Eisenia fetida and the obtained vermicompost. Biochar addition increased ($P < 0.05$) earthworm biomass, juvenile and cocoon numbers of *Eisenia fetida*, as well as the activities of dehydrogenase, cellulase, urease and alkaline phosphatase. Compared to the control, lignin degradation rate was enhanced up to 13.89% by biochar addition. Biochar addition also improved the vermicompost quality in terms of cation exchange capacity (CEC), dissolved organic carbon (DOC) degradation, humification, nitrogen transformation, toxicity to germinating seeds (*Brassica rapa L.*, Chinensis group) and heavy metals concentrations. The 6% bamboo biochar addition rate achieved maturity after 60 days of vermicomposting and resulted in the highest quality vermicompost based on parameters such as CEC, DOC, NH4+-N/NO3--N ratio, germination index and heavy metal concentration. We conclude that 6% biochar addition promoted earthworm growth and the vermicomposting of green waste.

Biochar addition increased the growth and reproduction of *E. fetida*, increased enzymatic activities, accelerated the decomposition of lignin and dissolved organic carbon, enhanced nitrification and humification, reduced the time required for the compost to be toxicity-free for seed germination, and enhanced the vermicomposting process. Biochar addition effectively promoted final vermicompost maturity and safety, as are reflected in the significantly higher CEC content, GI values.

Quality Analysis of Compost

After fermenting for 4 (four) weeks, compost quality analysis was carried out with parameters N, P, K, and C-Organic. The results of the analysis are presented in Table 1

Nutritional effect on leaf litter compost

Parameter	Min (%)	Max (%)	Analysis Results (%)
C organic	9.8	32	16.5
N	0.4		0.9
P	0.1		0.53
K	0.2		0.75

The calculation of the C/N ratio of dried bamboo leaves compost yields a value of 18.33 which is obtained from C-Organic/N. The ideal C/N ratio range is between 14 and 20. The C/N ratio is the ratio of carbon (C) to nitrogen (N) in organic matter.

Microbiological activity decreases when the C/N ratio is high. The results of the bamboo leaf litter compost analysis in Table 1 meet INS 19-7030-2004 standards. The analysis results of dried bamboo leaves compost are influenced by raw materials, microorganisms, and activators. Dried bamboo leaves containing 0.91% P and 0.74% K are the main raw material.

Additional ingredients in the form of cow dung contain 0.5% N, 0.25% P, and 0.5% K. The statement of raw material content is following the results of compost analysis in Table 1, with concentrations of N, P, K, and C exceeding the minimum limit determined by Indonesian National Standard (INS). Microorganisms have a key role in the composting process. For example, in dry bamboo leaves, there are microorganisms such as *Saccharomyces cerrevisiae, Lactobacillus sp,* and the fungus *Aspergillus sp* which play an important role. Along with that, cow dung used as raw material for compost also contains microbes such as *Bacillus sp., Corynebacterium sp., Lactobacillus sp., Aspergillus sp.* fungi, and *Candida sp.* Therefore, in an effort to manage the composting process effectively, it is important to understand and measure the population of these microorganisms in compost, including *Saccharomyces cerevisiae, Lactobacillus sp, Aspergillus sp, Bacillus sp., Corynebacterium sp., and Candida sp.* This will help you better optimize the composting process. In an effort to maintain environmental sustainability and support sustainable agriculture, much research has been conducted to explore the potential of natural organic materials, such as compost, in improving soil quality and

overcoming environmental pollution problems. One organic material that attracts attention in this context is compost produced from dry bamboo leaves. The latest research insights of using dry bamboo waste vermicompost as an effective bioremediation tool. The results of this research not only validate that dry bamboo waste vermicompost meets the criteria of INS 19-7030-2004, but also reveal the great potential of this compost in improving the chemical and physical properties of soil, as well as making a significant contribution as a nutrient needed for plant growth. This shows that dry bamboo waste vermicompost is not just organic waste, but is also a sustainable solution in an effort to support more environmentally friendly and productive agriculture.

Nutrition composition of compost

This vermicompost contains

- ❖ 1.14% nitrogen
- ❖ 0.65% phosphorus
- ❖ 0.88% potassium
- ❖ 16.54% humus content.

Benefits of Bamboo Waste Vermicompost

Bamboo waste vermicompost offers several benefits for soil health, plant growth, and sustainable agriculture.

Role of bamboo waste vermicompost on Soil

- Improved Soil Structure: Vermicompost can enhance soil aggregation, aeration, and water-holding capacity.
- Increased Nutrient Availability: Vermicompost is rich in nutrients like N, P, and K, making them available to plants.
- Enhanced Microbial Activity: Vermicompost promotes beneficial microbial growth, supporting soil health and fertility.

Role of bamboo waste vermicompost Plant

- ✓ Promotes Healthy Plant Growth: Vermicompost provides essential nutrients, supporting plant development and yield.
- ✓ Improved Crop Quality: Vermicompost can enhance crop quality by increasing nutrient content and reducing contamination.
- ✓ Increased Resistance to Pests and Diseases: Vermicompost can help plants develop resistance to pests and diseases.

Role of bamboo waste vermicompost Environment

- Sustainable Waste Management: Vermicomposting bamboo leaves reduces waste and promotes sustainable agriculture practices.
- Reduced Chemical Fertilizer Use: Vermicompost can decrease the need for synthetic fertilizers, minimizing environmental pollution.
- Carbon Sequestration: Vermicomposting can help sequester carbon in soils, mitigating climate change.

Economic Benefits

- Cost-Effective: Vermicomposting is a low-cost method for producing nutrient-rich compost.
- Increased Crop Yields: Vermicompost can lead to increased crop yields, improving farm productivity and profitability.

Conclusion

Bamboo waste vermicomposting offers a sustainable and eco-friendly solution for managing bamboo waste while producing nutrient-rich compost. This process utilizes earthworms to break down bamboo waste, reducing environmental pollution and promoting soil health. The resulting vermicompost can be used as a natural fertilizer, enhancing crop growth and reducing reliance on synthetic fertilizers. By adopting bamboo waste vermicomposting, we can promote a circular economy, reduce waste, and contribute to a more sustainable future.

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PARTHENIUM IN AGRICULTURE: FROM PEST TO POSSIBILITY

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Introduction to Parthenium

Parthenium (*Parthenium hysterophorus*), commonly referred to as Congress grass or Carrot grass, is an aggressive, fast-spreading weed belonging to the family Asteraceae. It derives its name "carrot grass" due to the morphological similarity of its leaves with those of the carrot plant. Although native to Mexico and Central America, this invasive species has established itself as a major ecological threat in India and various other tropical and subtropical regions. The first confirmed report of *Parthenium* in India dates back to 1955, from Pune, Maharashtra, believed to have arrived as a contaminant in imported food grain consignments. Since then, its spread has been rapid and relentless, colonizing vast landscapes with alarming speed. Today, it is estimated that over 35 million hectares of land in India are infested with *Parthenium*, affecting not only agricultural fields, but also roadsides, railway tracks, irrigation canals, drainage lines, and urban open spaces.

Identification Characteristics

Recognizing *Parthenium hysterophorus* in its early stages is crucial for effective management. The weed can be identified by the following morphological features:

- Height: Mature plants typically attain a height ranging from 1.5 to 2.0 meters.
- Branching: The plant is heavily branched, contributing to its bushy appearance.
- Stems and Leaves: Both are covered with fine, soft hairs, and the leaves are deeply lobed, resembling those of a carrot.
- Flowers: The plant produces small, white flowers, clustered at the tips of the branches.

Due to its similarity to harmless vegetation during early growth stages, *Parthenium* often escapes early detection, exacerbating its invasive behavior.

Mechanism of Spread

Parthenium primarily propagates through seed dispersal. A single plant has the astonishing capacity to produce between 5,000 to 25,000 seeds, and under ideal conditions, this number can escalate up to 944,000 seeds per square meter. These seeds are extremely lightweight and can be easily carried by wind, rainwater, animals, vehicles, and human activity. In addition, *Parthenium* exhibits vegetative regeneration, meaning that even cut stems or broken plant parts can regenerate into new plants, making manual control highly challenging.

Harmful Impacts of Parthenium Infestation

The proliferation of *Parthenium* poses multiple agronomic, ecological, environmental, and health hazards, including:

- Human and Animal Health Hazards: *Parthenium* produces toxic chemicals such as parthenin and other sesquiterpene lactones that can cause severe allergic reactions, including skin dermatitis, asthma, bronchitis, and hay fever in sensitive individuals. It is a major public health concern in both India and Australia.
- Agricultural Impact: The weed competes aggressively with crops for sunlight, water, nutrients, and space, resulting in reduced crop yields and economic losses for farmers.
- Environmental Degradation: It disrupts native flora by forming dense monocultures, reducing biodiversity, and altering soil chemistry. Its spread also affects grazing lands and natural ecosystems.
- Urban and Aesthetic Impact: In urban environments, it invades parks, gardens, and residential landscapes, decreasing their aesthetic value and increasing maintenance costs.

Challenges in Management

Despite various efforts over the decades, managing *Parthenium* remains a daunting challenge. No single method has proven to be entirely effective due to:

- High seed production and regeneration capacity.
- Resistance to some herbicides.
- High cost and labor-intensiveness of manual removal.
- Environmental concerns related to chemical use.

Hence, an Integrated Weed Management (IWM) strategy is recommended, combining multiple control methods for sustainable and long-term management.

Integrated Management Strategies for Parthenium Control

1. Manual (Mechanical) Control

Manual uprooting or cutting of *Parthenium* plants before they flower (typically during the early monsoon season) can effectively reduce seed spread. However, the process poses a health risk, especially to individuals with skin sensitivities or respiratory conditions. Therefore, protective measures such as gloves or polythene covers are essential during manual handling. Community-level participation is crucial, involving local residents, students, farmers, and municipal workers for widespread eradication.

2. Cultural Control

Encouraging the growth of competitive and fast-growing crops can naturally suppress *Parthenium* populations. Crops such as paddy (rice), maize, and pearl millet (bajra) are especially effective in shading out the weed and reducing its emergence through allelopathy and competition.

3. Legal and Policy Measures

Some Indian states, like Karnataka, have pioneered legal actions against the spread of *Parthenium*. Municipalities and local governing bodies are empowered to enforce weed control, particularly in public spaces. However, effective implementation requires community awareness, political will, and regulatory backing.

4. Chemical Control

Chemical herbicides offer a practical option for large-scale or non-crop area control, but they must be used judiciously:

- Glyphosate (1.0–1.5%) is widely used in non-crop areas for effective knockdown.
- Metribuzin (0.3–0.5%) and 2,4-D (1.0–2.0%) can be employed for selective weed control.
- For specific crops:
    - Soybean, tomato, and sorghum: Use Alachlor at 2.0 kg/ha.
    - Post-sowing application: Metribuzin at 0.5–0.75 kg/ha is effective.

Farmers should always consult agronomists or extension personnel before applying herbicides to ensure crop safety and efficacy.

5. Biological Control

Biological control is an environmentally sustainable strategy that involves the use of natural enemies to suppress *Parthenium*. One notable success is the leaf-feeding beetle, *Zygogramma bicolorata* (family: Chrysomelidae), introduced from Mexico to India in 1982. This insect has shown significant effectiveness in reducing *Parthenium* populations.

- It lays light yellow eggs on the upper leaf surfaces.
- Eggs hatch in 4–7 days, and the insect completes its life cycle in 22–32 days.
- Both larvae and adults feed voraciously on the plant, defoliating it and thereby suppressing its growth and reproduction.

Unlike other methods, biological control is self-sustaining and environmentally benign, although it may take time to establish and produce visible results.

Applications of Parthenium in Agriculture

1. Green Manure and Composting

- Parthenium biomass, when decomposed, can be used as a green manure to improve soil fertility.
- It enhances organic matter content, microbial activity, and improves soil structure.
- Composting parthenium with other organic wastes (e.g., cow dung, poultry litter) reduces its allelopathic and toxic effects.

2. Bio-pesticidal Properties

- Parthenium contains allelopathic compounds (like parthenin) with insecticidal, nematicidal, antifungal, and herbicidal properties.
- Extracts from leaves, stems, or flowers can be used to prepare natural pest repellents or bio-pesticides.
- Effective against pests such as:
    - Aphids
    - Whiteflies
    - Root-knot nematodes
    - Leaf-eating caterpillars

3. Weed Suppressant / Natural Herbicide

- The allelopathic compounds in Parthenium can suppress germination and growth of other weeds.

- Extracts or mulch made from parthenium residue can inhibit the growth of problematic weeds in fallow fields.

4. Vermicomposting

- When mixed with other organic waste in the right proportion, Parthenium can be used in vermicomposting with earthworms like *Eisenia fetida*.
- The resulting vermicompost is rich in nutrients and safe for crop use.

5. Soil Amendment and Mulching

- Dried Parthenium residue can be used as organic mulch to:
    - Conserve soil moisture
    - Suppress weeds
    - Improve soil organic content

6. Biochar Production

- Parthenium biomass can be converted into biochar via pyrolysis.
- Biochar improves soil pH, water retention, nutrient holding capacity, and carbon sequestration.

7. Source of Botanicals for Research and Industry

- Used in the synthesis of botanical pesticides, herbal formulations, and bioactive extracts.
- Parthenin and other lactones have pharmaceutical and industrial applications that are under research.

Conclusion

Parthenium hysterophorus L., though widely considered a harmful invasive weed, has several valuable applications in agriculture when properly managed. It can be used as green manure, bio-pesticide, compost, biochar, mulch, and in vermicomposting and phytoremediation, contributing to soil fertility, pest control, and reduced reliance on chemical inputs. With appropriate handling before flowering and proper processing to neutralize toxins, Parthenium can be transformed from a threat into a useful resource, supporting sustainable and eco-friendly farming practices.

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APICAL DOMINANCE: EFFECT OF APICAL PINCHING IN OKRA (Abelmoschus esculentus)

Article ID: AG-V05-I07-51

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Abstract

Apical dominance is a natural phenomenon in plants wherein the terminal bud suppresses the growth of lateral buds through hormonal influence, primarily auxins. This study explores the role of apical bud pinching in managing apical dominance to enhance the growth and yield attributes of okra (Abelmoschus esculentus). Various pinching treatments were evaluated for their effect on plant morphology, flowering, yield, and seed quality. The results highlighted that pinching the terminal bud significantly improved lateral branching, delayed flowering, and enhanced pod yield and seed recovery compared to unpinched plants. This paper discusses the physiological basis of apical dominance, the impact of its manipulation through pinching, and recommendations for optimizing okra productivity.

Keywords: Apical dominance, Auxins, Okra, Pinching, Yield improvement, Hormonal regulation

Introduction

Apical dominance is a vital physiological process in higher plants, where the terminal (apical) bud inhibits the growth of lateral (axillary) buds through hormonal regulation, predominantly by auxins produced at the shoot apex. This phenomenon ensures vertical plant growth and limits lateral branching. However, in horticultural crops like okra (Abelmoschus esculentus), breaking apical dominance through apical bud pinching has shown potential benefits in improving lateral shoot formation, overall canopy structure, and ultimately, crop yield (Patil et

al., 2012). This article reviews the influence of apical dominance and evaluates the agronomic advantages of apical bud pinching in okra cultivation, emphasizing its effects on plant growth, flowering, yield, and seed quality.

Contents

Causes of Apical Dominance

Apical dominance is regulated by plant hormones, notably:

- Auxins (Indole-3-Acetic Acid, IAA): Synthesized at the shoot apex and transported basipetally, auxins inhibit lateral bud outgrowth.
- Cytokinins: While promoting cell division, cytokinins are antagonistic to auxins in apical dominance regulation, promoting lateral bud activation when auxin levels fall (Sachs & Thimann, 1967).

Effect of Apical Bud Pinching on Growth

Pinching the terminal bud disrupts apical dominance, redistributing auxins and promoting lateral branching. Studies have shown that pinching improves photosynthetic activity, leaf area, and overall plant vigor (Patil et al., 2012). Pinching 20 days after sowing notably increased branch numbers and vegetative growth (Sajjan et al., 2002; Firoz et al., 2010). Gujar and Srivastava (1972) also observed significant growth changes when pinching was performed early in the plant's lifecycle.

Impact on Yield and Seed Quality

Apical pinching enhances okra productivity by reallocating assimilates towards lateral branches, thereby increasing flowering and fruiting sites. Reddy et al. (1997) reported a 9.6% increase in seed yield due to pinching. Additionally, it improved fruit girth, seed weight, and seed vigor (Bhat, 1994; Sajjan et al., 2004).

Influence of Pinching Time on Growth, Flowering, and Yield

Timing of pinching significantly affects plant growth and productivity:

- At 30 days: Delayed flowering (57.4 days), higher final plant height (100.03 cm), total fruit yield (20,857.3 kg/ha), and more seeds per pod (49.4)
- At 45 days: Maximum edible fruit length (14.71 cm), branches per plant (3.78), and plant height at first picking (30.65 cm)AA
- Control (No pinching): Earliest flowering (44.63 days) but lower pod yield and seed count

Case Study: Effect of Pinching Treatments in Okra cv. Pusa A4

A field experiment using a randomized block design (RBD) with three replications tested four treatments:

- T1: Terminal bud pinching
- T2: Terminal bud + one leaf pinching
- T3: Terminal bud + two leaves pinching
- T4: Control (no pinching)

Findings:

- T1 produced the highest number of leaves (38.33), branches (4.60), pods per plant (22.25), pod weight (74.77 g), pod girth (6.45 cm), and yield per plot (4.037 kg).
- T4 had the tallest plants (52.50 cm) but the lowest yield (2.430 kg).
- Excessive pinching (T3) reduced pod length and yield.

Physiological Impact

Pinching modified hormonal balance by lowering auxin concentration at the apex, thereby activating dormant lateral buds and improving nutrient allocation. Enhanced photosynthetic surface area and nutrient mobilization resulted in increased fruit yield and seed quality.

Conclusion

Apical dominance is a pivotal factor in plant architecture and resource management, predominantly governed by auxins. Its manipulation through apical bud pinching significantly improves vegetative growth, flowering characteristics, and yield in okra. The study confirmed that moderate pinching (T1) effectively enhances lateral branching, pod yield, and seed recovery, while excessive pinching (T3) is detrimental.

These findings suggest that strategic pinching is a simple, low-cost, and profitable agronomic practice suitable for sustainable okra production. Its adoption could improve productivity, fruit quality, and economic returns for farmers.

Acknowledgement

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WONDER HERB STEVIA REBAUDIANA BIOMOLECULES: A MULTIFUNCTIONAL NATURAL SWEETENER WITH THERAPEUTIC, CULINARY, AND INDUSTRIAL APPLICATIONS

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Abstract

The rising global incidence of diabetes, obesity, and metabolic disorders has led to an increased demand for natural, non-caloric sweeteners. Stevia rebaudiana, commonly known as stevia, has emerged as a promising alternative to synthetic sweeteners due to its high-intensity sweetness and therapeutic properties. Rich in steviol glycosides, especially sativoside and rebaudioside A, stevia offers a range of medicinal, culinary, cosmetic, and industrial applications. This paper reviews its botany, phytochemistry, cultivation practices, extraction methods, value-added product development, and therapeutic benefits. It further explores its economic potential and future prospects as a wonder herb in the functional food and nutraceutical industry.

Keywords : Stevia, Steviol glycosides, Natural sweetener, Medicinal properties, Functional foods, Value-added products, Nutraceuticals.

Introduction

Modern dietary habits have resulted in overconsumption of refined sugars, contributing to non-communicable diseases. Stevia (Stevia rebaudiana), a perennial shrub native to South America, offers a natural solution with its high-intensity sweetness and zero-calorie content. Unlike artificial sweeteners, stevia also offers multiple pharmacological benefits, making it valuable for both preventive and therapeutic purposes. The increasing prevalence of lifestyle

disorders like diabetes, obesity, and cardiovascular diseases has raised global concern about excessive consumption of refined sugars and artificial sweeteners. As a result, there is a growing demand for safer, natural alternatives. Stevia (Stevia rebaudiana), a perennial herb native to Paraguay and Brazil, has gained significant attention as a natural, non-caloric sweetener. The plant's leaves contain high concentrations of steviol glycosides, primarily stevioside and rebaudioside A, which are 150–400 times sweeter than sucrose. Apart from its sweetening capacity, stevia exhibits diverse medicinal properties, including, Antidiabetic, Antioxidant, Antihypertensive, Anti-inflammatory and Antimicrobial activity. In addition, stevia blends well with other natural extracts (e.g., lemongrass, monk fruit) to create functional, value-added products that are not only palatable but also health-promoting.





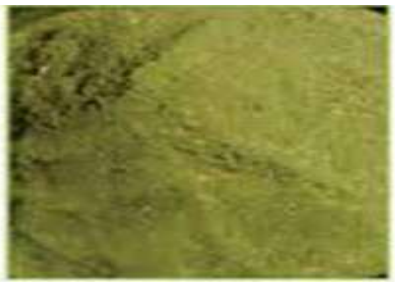






Products of stevia

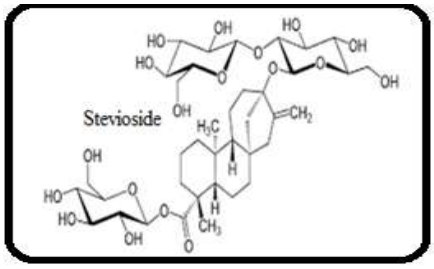




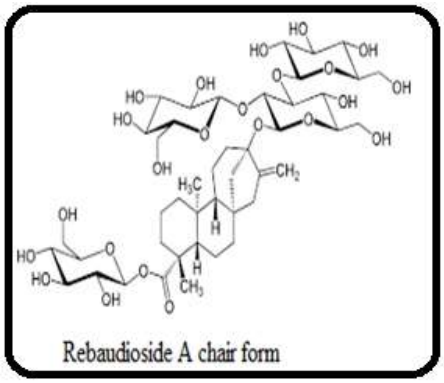
2. Phytochemistry and Molecular Components

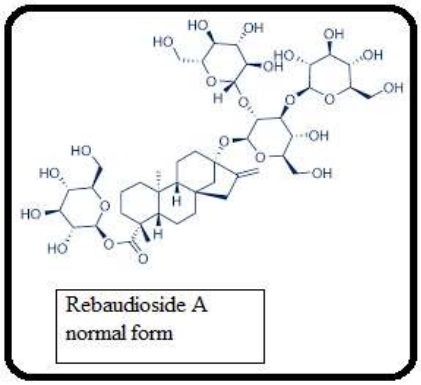
The major bioactive compounds of Stevia rebaudiana are steviol glycosides, along with various secondary metabolites. These glycosides have a diterpenoid backbone (steviol core) and various sugar moieties that influence sweetness and taste quality.

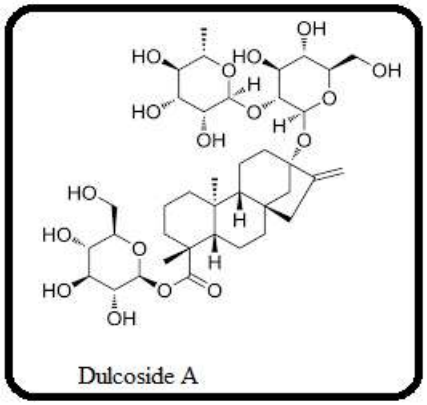
S. No	Compound	Molecular Formula	Relative Sweetness
1.	Stevioside	$C_{38}H_{60}O_{18}$	150–300× sweeter than sucrose
2.	Rebaudioside A	$C_{44}H_{70}O_{23}$	200–400× sweeter
3.	Dulcoside A	$C_{38}H_{60}O_{17}$	~30× sweeter
4.	Steviolbioside	$C_{32}H_{50}O_{13}$	~30–40× sweeter

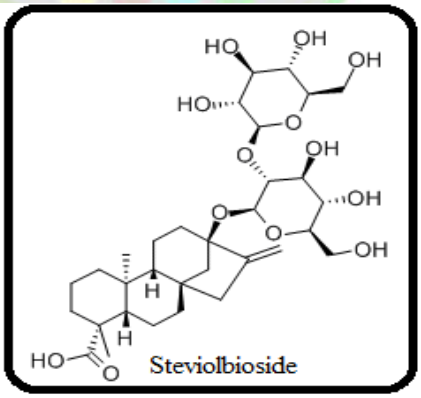












3. Overall Applications of Stevia

3.1 Medicinal Applications

Stevia demonstrates multiple therapeutic properties:

S. No	Medicinal Benefit	Mechanism of Action
1.	Anti-diabetic	Stimulates insulin secretion

2.	Antihypertensive	Vasodilation and calcium channel blocking
3.	Anti-inflammatory	Inhibits cytokines
4.	Antioxidant	Scavenges free radicals
5.	Anti-obesity	Appetite regulation, zero calorie
6.	Anti-cancer	In vitro studies show apoptosis in tumor cells
7.	Dental Health	Antimicrobial action against caries-causing bacteria

3.2 Cosmetic Applications

Skin creams (anti-aging), Hair care products, Lip balms, and Dental care products.

3.3 Industrial Applications

Sugar-free chewing gum manufacturing, Pharmaceuticals (syrups, lozenges), Veterinary feeds (anti-parasitic agent).

3.4 Culinary Applications

Functional beverages, Bakery items,Dairy desserts, Sugar-free confectionery and Nutraceutical products

4. Cultivation and Extraction

4.1 Cultivation

Soil: Well-drained sandy loam (pH 6.5–7.5), Climate: Subtropical and tropical (15–30°C), Propagation: Stem cuttings and Harvesting: 3–4 months after planting.






4.2 Cultivation of Stevia for drip system.

Location: Agricultural Research Plot, Soil Preparation: Sandy loam, pH 6.5–7.5, Propagation: Vegetative stem cuttings planted at 30 cm × 45 cm spacing, Irrigation: Drip system and Fertilization: Organic manure + balanced NPK fertilizers.

4.3 Harvesting

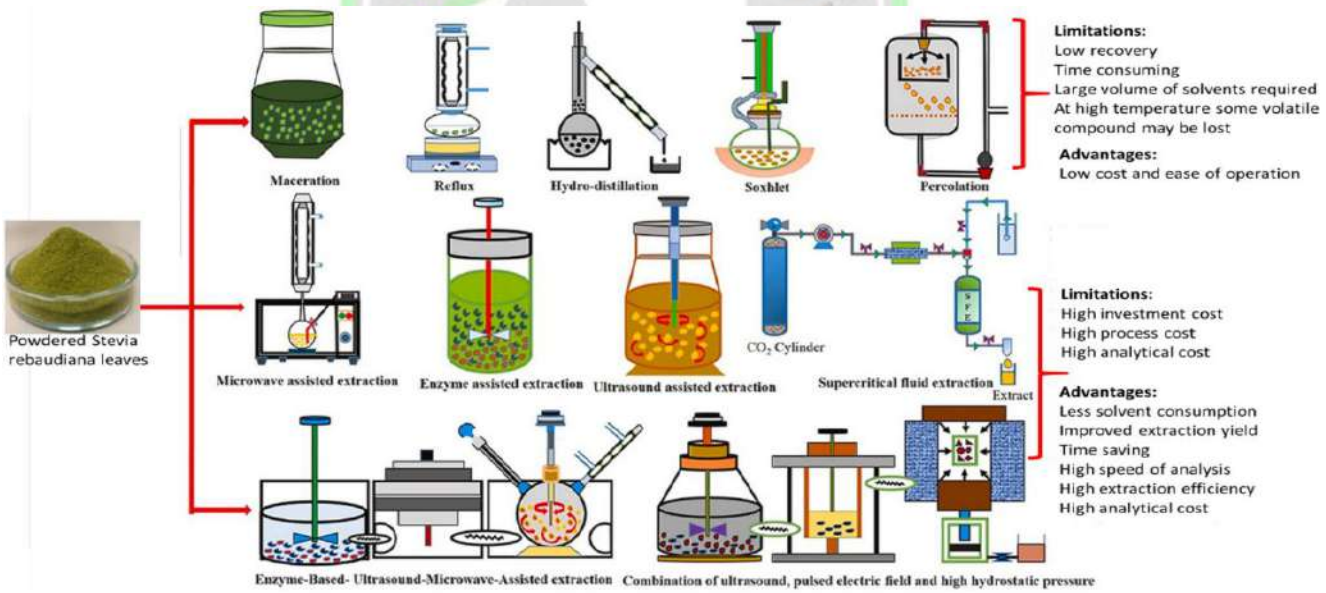
First harvest done at 90–120 days before flowering for maximum glycoside concentration. Leaves dried in shade to preserve active compounds.

4.4 Extraction Process

Leaf Harvesting & Drying, Water or Ethanol Extraction, Filtration and Concentration Purification (Ion exchange chromatography), Crystallization and Dry Powder Formulation.

4.5 Extraction of Steviol Glycosides

Water Extraction Method: Crushing and soaking dried leaves in warm water (50–60°C) for 3 hours. Filtration to remove solids. Concentration under reduced pressure. Purification using ion-exchange resin columns. Crystallization of steviol glycosides.



5. Value-Added Product Development

Stevia can be used to formulate various functional food and health products:

	Product Type	Application
1.	Herbal Tea	Lemongrass-stevia dip tea

2.	Sugar-Free Beverages	Diabetic-friendly soft drinks
3.	Bakery Products	Low-calorie cakes and biscuits
4.	Confectionery	Sugar-free chocolates and jams
5.	Cosmetics	Skin creams, hair products, lip care
6.	Pharmaceuticals	Sugar-free syrups, lozenges

5.1 Formulation of Value-Added Product

Example: Lemongrass-Stevia Dip Tea, Ingredients: Dried stevia leaf powder, Dried lemongrass leaf powder, Tea bag filter paper. Procedure: Blend 60% stevia leaf powder with 40% lemongrass powder. Pack 2 grams of blend in each tea bag. Seal and label.

5.1 Quality Control Parameters

Sensory evaluation (taste, aroma), pH stability, Sweetness retention, Microbial load analysis, Shelf-life studies.

5.2 Packaging & Marketing

Food-grade packaging materials used to preserve freshness. Labeled as "100% Natural Sweetener | Diabetic Friendly | Antioxidant Rich".

6. Economic and Marketing Potential

Increasing global demand due to rising health awareness. Used by major industries (e.g., Coca-Cola, PepsiCo). Widely accepted in Japan, USA, Europe, and India. Opportunities for farmers, entrepreneurs, and nutraceutical companies.

7. Challenges and Future Prospects

Bitterness at high concentrations (taste masking needed). Need for stable breeding programs (high rebaudioside A varieties).Regulatory standardization. Integration into broader health-based food systems.

Conclusion

Stevia stands as a wonder herb offering immense potential as a natural sweetener with multifunctional applications. Its incorporation into food, cosmetic, and pharmaceutical industries can help address global health challenges while offering economic opportunities.

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APPLICATION OF ARTIFICIAL INTELLIGENCE IN MODERN HORTICULTURE

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Abstract

New agricultural technologies have increased agricultural capacity and efficiency. Artificial intelligence-based methodologies have been increasing global agricultural challenges, the application of artificial intelligence technology in the agricultural field is increasingly a trend, especially in the production of fruit products, intelligent identification technology to significantly improve production efficiency, and optimize yield and quality. Smart agriculture, which uses technology and data analytics, can improve social, economic, and environmental sustainability. Information on pest control techniques, yield maximization, quality fruit production, appropriate Soil treatment, Pest control system, Disease control information, Information on farm technology and innovation etc,. This paper presents a comprehensive investigation of smart technologies in agriculture, their impact on sustainability, architectural design, and major variables influencing their adoption based on recent research. We critically analyze smart agriculture to show how it might reduce environmental impact, boost economic growth, and promote social inclusivity. This research highlights the importance of artificial intelligence in agriculture and its domains.

Keywords: Artificial intelligence, Big Data Analytics, Horticulture, Machine Learning

Introduction

India has the opportunity to grow a wide variety of horticulture crops due to its various soil, climate, and agro-ecological zones. Horticultural crops, which comprise fruits, vegetables, medicinal, aromatic, and decorative plants, are important components of a balanced diet, sources of medication and fragrance, as well as possessing a variety of aesthetic benefits for people.

Fruits and vegetables contribute to 90% of all horticulture production in the nation. Our nation currently produces 10% of the fruits and 14% of the vegetables consumed worldwide, placing us second only to China in terms of acreage and production of these commodities. Horticulture crops contribute significantly to India's economy by raising rural residents' incomes along with generating jobs for young people.

The development of intelligent systems has increased the potential to improve the cultivation and management elements of horticulture crops on the basis of advances in technology and information analysis methodologies. Surprisingly, horticulture has seen an increase in agricultural technology research and commercialization while having the least amount of digitalization. The sector is nevertheless exposed to a wide spectrum of biotic and abiotic stress, which affects the yield and quality of the produce. In such cases, implementing the most recent technical advancements and solutions can result in better and more effective manufacturing methods.

It has many uses in the horticulture sector. Machines may frequently be made to perform tasks more effectively than people, including planting, watering, and harvesting as well as testing new systems. In order to increase yield, the horticulture sector needs workers with expertise in artificial intelligence. Artificial intelligence (AI) technologies help produce healthier crops, provide information on current weather conditions, such as temperature, rain, wind speed, wind direction, solar radiation, pest control, and soil and growing conditions, organise data for farmers, lessen their workload, and enhance the food supply chain (Manaware, 2020).

APPLICATIONS OF AI IN HORTICULTURE

Precision farming AI integrate various sources of raw data like soil sensors, weather stations, IoT and satellite images. These devices help in making decisions like the application of pesticides, fertilizers and irrigation. It utilizes real-time data to determine water requirements in particular fields, thus saving wastage of water used. AI reduces resource waste and reduces environmental impact by examining treatments for crop disease with limited resources.

Prediction of weather

Weather prediction is an important component in horticulture industry as numerous intercultural operations depends on weather. Machine Learning technology can be handy in using algorithms in connection with satellites to predict changing weather on daily basis. These algorithms can also be used in predicting crop health without any contact with large fields.

Machine learning also widens the scope of prediction and detection of pest and pathogens in the farmer's field.

Soil Health Analysis

Soil health in terms of both moisture and nutrients are basic need for horticultural crops. Nutrient and moisture rich soils not only enhance [6] yield but also increases fruit quality. Both artificial Intelligence and Machine Learning may develop algorithms and sensors for detection and quantification of moisture and nutrients in the soil. Robots may also be used in quantification of soil nutrients which may further provide predictive analysis for recommended dose of fertilizers and irrigation. Cash crops like Cashew nut and rubber are exhaustive crop and require high dose of nutrients. Machine learning and robots may prove solving such problems in these crops.

Agrochemical Production

Automation in Horticulture Post harvest Management Soil and Plant Analysis Horticultural crops require numerous synthetic chemicals such as plant bio regulators, weedicides, pesticides etc for high production and quality. These chemicals have tendency to remain in soil and plant enhancing toxicity. Moreover, these chemicals go in food chain which creates various metabolic ruptures. Machine learning with Big Data Analytics can be used to develop models which may help in production of appropriate agrochemicals by capturing images of pathogens, weeds and pests (Baruah, 2019).

Automation system in Irrigation

The Internet of Things (IoT)-based smart irrigation system is a device that can automate the irrigation process by monitoring the soil's moisture content and meteorological conditions. Irrigation is one of the most labor-intensive processes in farming which can be avoided by artificial intelligence because it is aware of historical weather patterns, soil quality, and the type of crops to be grown.

Weed Control

Given that an estimated 250 kinds of weeds have developed resistance to herbicides, controlling weeds is one of farmers' main priorities. A startup business in California created a robot named "See & Spray" that purportedly uses computer vision to track and precisely spray on weeds. Herbicide resistance can be avoided with precise spraying. It accurately sprays

fertilizers where they are needed, on the plant. This might reduce the amount of herbicide needed to spray the entire field by around 90%.

Produce maturity identification

Identifying the stage of fruit ripeness requires taking pictures of various crops under white/UV-A light. Particularly in the case of extremely perishable horticultural products, farmers might develop multiple maturity grades based on the crop/fruit category and place them into separate stacks before delivering them to the market. Harvesting at the right maturity would also increase post-harvest shelf life.

Post Harvest Management

Post harvest processes such as cleaning, sorting and grading can be done using Artificial Intelligence and Robots. Sensors can also be used in storage and warehouses to detect stored pest and pathogens. About 40% of horticultural produce is wasted as post harvest loss. Machine learning and Digital Image Processing can be used in reducing such losses which may enhance annual horticultural production (Kamilaris, 2018).

Detection of pathogenecity

Horticultural crops are more prone to pest and diseases in comparison to other cereal crops. These pest and diseases not only reduce yield but also decreases quality which further fetch lesser price in the market. Algorithms in integration with captured images may detect type of diseases which may further predict its control. This technology can be used in vineyards where grape leaves can be detected with diseases. Due to improper knowledge farmers generally spray pesticides and fungicides equally in all plants which enhance cost of input and wastage of chemicals. Machine learning hence can develop algorithms which shall direct farmers where exactly these chemicals are required which will further reduce cost of input and wastage (Sennar, 2019).

Stress Management

Horticultural crops like fruits and vegetables in their production cycle go through different biotic and abiotic stresses. These stresses at any point of time may harm quality and production of such crops. Digital Image Processing for example may help in detection of such stresses and Machine learning as a result with use of algorithm can help in overcoming such stresses. Stress management can be released through IT technologies like IOT, AI and cloud etc.

Application in data analysis

Accurate agricultural data analysis plays a crucial role in shaping national agricultural development strategies. Leveraging artificial intelligence technology to optimize agricultural data analysis can effectively provide more precise and robust support for the country's agricultural strategies. The research highlighted the significant potential of integrating data mining technology into agricultural production to improve the efficiency and scientific validity of agricultural management and operations.

Conclusion

Horticulture industry at present revolves around numerous problems which is hampering yield and productivity of crops. Being profitable industry farmers cannot avail the profit through this industry because of such variables. Automation technology like Artificial Intelligence, Big Data Analytics, Digital Image Processing, Block Chain Technology can solve such real issues which directly or indirectly shall improve production and quality of farmers produce. These technologies can also be used in reducing environmental damage developed through improper use of synthetic chemicals used in producing fruits and vegetables.

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QUALITY CODING: POTENTIAL OF AI TO REVOLUTIONIZE FOOD QUALITY MONITORING

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Introduction

"Health is wealth". Our health, nutrition requirement as well as productivity is dependent on quality of food we consume. Food quality consists of external factors such as appearance (e.g., size, shape, color, gloss, and consistency), internal factors (e.g., chemical, physical, microbial), as well as texture and flavour, the combination of which decides the food product's acceptability to the consumers. Ensuring high food quality is important for consumer satisfaction, public health, and the overall success of the food industry.

Food processing industry plays a vital role in India's economic growth, contributing significantly to the country's GDP (IBEF, 2025). Food processing increases the value of agricultural products with minimum wastage and ensures food security. Thus assuring the safety and quality of food is of great importance not only at domestic level but also at industrial level, failing which may lead to mass distribution of contaminated food products. Unsafe food can lead to a large number of foodborne diseases. It is estimated that, worldwide, 600 million people (1 in 10 people) fall ill after eating contaminated food and 4,20,000 die every year (WHO,2024).

Artificial Intelligence (AI) is an area of computer science that facilitates the creation of intelligent machines that work and react similarly to humans by imitating human thought process and learning ability. Industries that were early adopters of AI include speech recognition, facial recognition, biometrics, planning, and computer-based problem solving. AI algorithms learn and improve their effectiveness similar to the learning process for human food safety and quality professionals (Greenfield et al. 2019).

AI has the potential to considerably improve food quality monitoring across the supply chain-from farm to fork. AI plays a vital role in ensuring food quality by improving the speed and precision of detection of defects or contamination, streamlining supply chains, and maintaining uniform quality throughout production. Implementation of AI allows companies to reduce human errors, reduce waste, and improve overall food safety and consumer trust.

Food quality monitoring is very important for ensuring the safety and quality of food products. It helps to prevent foodborne illnesses by detecting contaminants, defects, and quality issues in food products. Food quality monitoring can aid manufacturers to comply with food safety regulations and standards. It also helps to maintain brand reputation by ensuring that products meet quality and safety standards. Since it helps to detect defects and quality issues at the earliest, the waste produced can be reduced to the minimum which results in improved efficiency.

Challenges faced by traditional systems in food quality monitoring

Food quality monitoring faces numerous challenges in the present scenario including contamination risks, complex supply chains, manual error, data management and regulatory compliance. These challenges make traditional systems insufficient to meet their requirements. Furthermore, food safety detection remains a difficult issue; the adulteration of food is increasing and it is difficult to detect adulteration at every stage. This is due to the high analytical cost, long analysis time, and lack of resources required for these sophisticated techniques (Yu, W 2025). Traditionally, food quality is determined using a range of destructive and time-consuming approaches with modest analytical performance, underscoring the urgent need to develop novel analytical techniques (Abdo, 2023).

Potential of AI in food quality monitoring

The food industry requires systemic transparency, predictive capabilities, and real-time intelligence. This is where AI is emerging as a game-changer. To resolve the complex issues in food safety and improve detection efficiency and accuracy, AI has brought new possibilities with its powerful data processing capabilities, efficient automation characteristics, and accurate analysis and judgment (Barthwal, et al., 2024). AI can be utilised in many processes such as sorting, optimizing supply chain management, quality control, reducing food waste etc. Figure 1 shows a flowchart for the steps involved in developing AI model (Mavani et al., 2022)

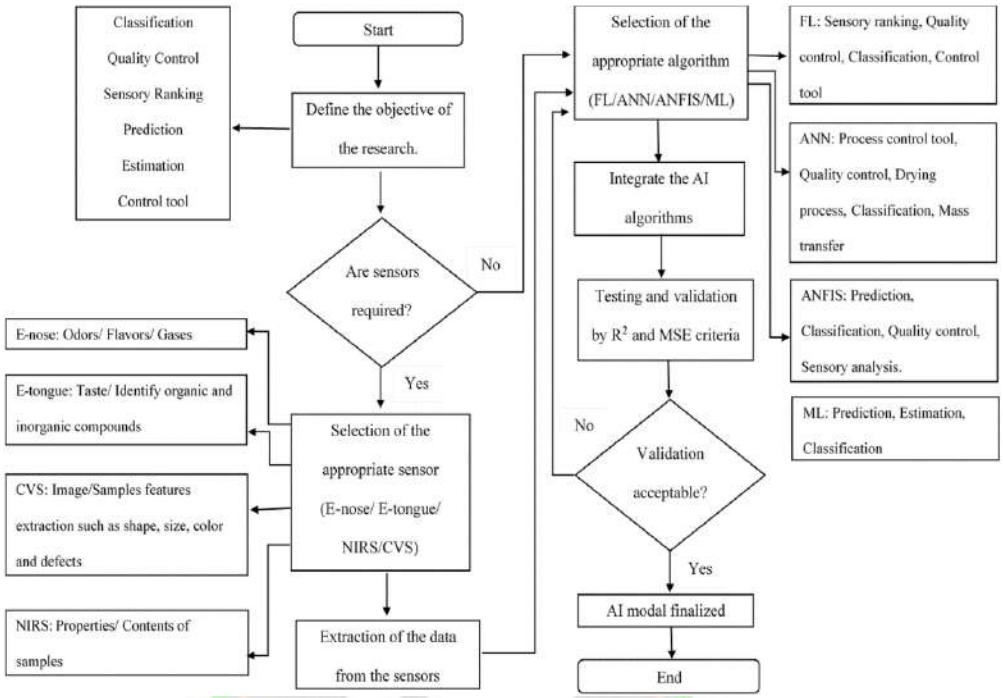


Figure 1. Flowchart for developing AI model (Mavani et al, 2022)

a) Sorting Systems

AI-based food sorting technologies employ sophisticated algorithms and machine learning to evaluate and classify food products according to quality standards such as size, color, deformations, ripeness etc. This innovation greatly minimizes human error and quickens the processing speed, which is essential for preserving the freshness of fruits and vegetables. Furthermore, these systems have the capability to learn and enhance their performance as they analyze more data, consistently improving sorting accuracy.

'Tomra Systems', a prominent player in the sorting solutions market, exemplifies this technology well. Their AI-driven systems can handle thousands of food items per minute, sorting them with remarkable precision. This guarantees that consumers receive the highest quality products while assisting producers in minimizing waste and boosting efficiency, resulting in improved resource management and reduced operational costs.

b) Optimizing Supply Chain Management

AI greatly improves the efficiency of supply chains in the food sector by predicting demand, optimizing inventory, and enhancing logistics. AI systems examine past sales data, weather predictions, and market trends to anticipate future product demand, enabling businesses to

prepare and modify their inventory levels accordingly. This minimizes both overstock and stock outs, ensuring that perishable items are handled properly.

IBM's Watson Supply Chain showcases these functionalities. It offers insights that assist companies in anticipating, evaluating, and addressing real-time disruptions. This proactive approach maintains smooth supply chain operations, decreases waste, and guarantees that fresh produce and other food products are accessible to consumers when and where they are needed.

c) Quality Control

Quality control utilizing AI involves constant observation and evaluation of the production process to guarantee that the products comply with safety standards and quality requirements. AI-based visual inspection systems are capable of identifying flaws or contaminants that human inspectors may overlook. Additionally, these systems can learn from each examination, enhancing their precision and performance. Food products can be scanned in real time on production lines using AI algorithms and high-resolution cameras. These systems are far more accurate and reliable than human inspectors at spotting flaws like discoloration, bruising, or irregularities in shape (Figure 2). For example the minute cracks in eggs can be detected with the help of AI intervention which is impossible to achieve with manual inspection.

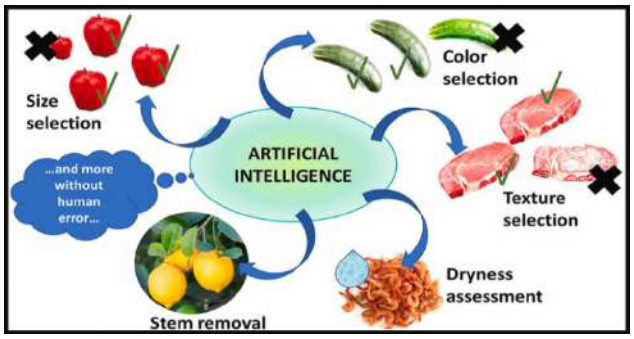


Figure 2. AI Analytics applications for quality control of food- Zhu et al. (2021).

(Image credits: https://doi.org/10.1016/j.crfs.2021.03.009*)*

d) Predicting Spoilage and Shelf Life

To predict spoiling, AI models examine environmental data, such as temperature, humidity, and storage conditions with the help of sensors. Predictive modelling based on these sensor data helps to adopt proper action which in turn reduce or avoid the spoilage of the product. This minimizes waste and guarantees that consumers receive fresher products by enabling food producers to optimize distribution and storage.

e) Microbial Contamination Detection

Biosensors can be used to collect data which can be analyzed to detect potential microbial contamination, such as E. coli or Salmonella, at the earliest and more reliably than conventional lab methods.

f) Smart Packaging and IoT Integration

With smart packaging and the Internet of Things (IoT), artificial intelligence (AI) can track food conditions in real time. Sensors that monitor temperature, freshness, or gas emissions notify suppliers and retailers of possible hazards, before goods are delivered to customers,

g) Data-Driven Decision Making

AI can compile information from the sourcing, processing, transportation, and retail stages of the supply chain to provide producers with a comprehensive view of their food quality metrics. This makes it easier to comply with regulations and allows for quicker, better-informed decisions.

Reducing Food Waste

AI plays a crucial role in reducing food waste by inspecting which items are frequently discarded and detecting patterns that may suggest inefficiencies in food utilization. AI systems can recommend modifications to purchasing decisions and recipe design by using this data, aiding restaurants and other food service providers in reducing waste and saving money.

AI technology is being used by 'Winnow Solutions' to assist kitchens in monitoring and analyzing their waste. The system identifies and logs what gets thrown away and uses this data to provide guidance on how to boost food preparation and consumption. This innovation contributes to reducing environmental impact and enhances profitability by reducing unwanted expenses linked to food waste.

Real-World Impact

Start-ups as well as large food companies are investing in quality monitoring systems driven by AI. For example, 'Nestlé' uses AI to monitor milk quality at collection points which helps to improve safety and farmer accountability. 'Nestlé' heavily incorporates this technology throughout its production lines. By continuous monitoring of the manufacturing process using their AI-enabled cameras and analytical tools, deviations from set quality standards are being efficiently identified. This not only ensures the safety and quality of food but also aids in adhering to increasingly strict health and safety regulations, thereby safeguarding consumer

health and bolstering brand reputation. 'TOMRA Food', the manufacturers of sensor based sorting machines and integrated post-harvest solutions for the food industry, uses AI-powered optical sorters to detect and eliminate damaged fruits, vegetables, and nuts. 'NotCo', a plant-based food company by analysing molecular data with the help of AI, replicates the texture and flavor of animal products.

AI Challenges

Even though AI technologies have a lot of potential for the food industry, there are still a number of barriers that prevent them from being fully utilized.

a) **Data Quality and Availability**

One of the most difficult tasks in the food industry is gathering high-quality data for supply chain management, crop monitoring, and food safety. We have to set up reliable data collection protocols to aid in this process. This ensures data accessibility and integrity while providing the food industry with reliable information.

b) **Complexity and Variability of Food Systems**

Developing AI systems to comprehend the production, processing, and delivery of food necessitates a complex strategy that takes into account a wide range of variables. Furthermore, training machine learning models using the data on those processes is challenging. Model development and deployment are hampered by the lack of standardized data formats, protocols, and practices across various food industry segments, which adds to the complexity. These issues needs to be tackled by putting strong interoperability solutions into place and keeping a track record of successfully combining various systems and data sources.

c) **Regulatory and Ethical Considerations**

Privacy, security, fairness, accountability etc., are the examples of some of the regulatory and ethical concerns being raised due to the integration of AI in the food industry. We have to carefully negotiate these regulatory environments to fully utilize AI and ML's potential while guaranteeing adherence to strict data protection laws and moral standards.

d) **Skills Gap and Talent Shortage**

The food industry's ability to successfully adopt AI depends on having access to specialized knowledge and abilities in data science, machine learning, and domain expertise. The sector faces a significant lack of skilled workers with the necessary technical know-how and

domain-specific knowledge. Businesses must encourage teamwork and give their staff training in order to bridge this skill gap.

Conclusion

Food quality and food quality monitoring are essential for ensuring consumer health, maintaining brand reputation and promoting sustainable food systems. By prioritizing food quality monitoring, food business can deliver high-quality and safe products to their customers and also improving their performance and competitiveness in the market. The food production become increasingly complex& diverse to meet the needs of increasing population. The traditional quality monitoring system is unable to keep up the pace with the increasing demands of consumers due to its tedious and laborious nature. Artificial Intelligence can help address the challenges faced by traditional methods and improve food quality monitoring in several ways. Food safety standards are essential to avoid spoilage and foodborne illness. Ensuring the quality of food is crucial for both consumer health and business success. Food quality monitoring plays a vital role in maintaining the safety, nutritional value and sensory attributes of food products.

Applications of AI in the food sector highlight a revolutionary period characterized by increased customer satisfaction, sustainability, and efficiency. However there are some constraints for adapting AI systems via high investment for implementation, ethical and legal concerns, chances of job reduction in rural areas, extend of reliability and accuracy in case of food safety management etc. All these key constraints needs to be addressed and rectified in order to facilitate adaptation of AI in food industries for a better and safer future. Many industries are simplifying processes and establishing new benchmarks for quality and safety by incorporating AI. AI has enormous potential to solve pressing issues like environmental sustainability and food security, offering a bright future. AI's role in the food industry is expected to grow as its use spreads, further impacting the production, processing, distribution, and consumption of food. In order to remain competitive and adaptable to the ever-changing demands of the global market, industry stakeholders must embrace this technological wave.

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THE GREEN GOLD IN BANANA FARMS: HOW PSEUDOSTEM WASTE IS BEING REUSED

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Introduction

Bananas are the leading food crops in global agriculture, representing 16% of the world's fruit trade (Gupta *et al*., 2023). It is not only just a fruit; it's a full package of resource. Apart from yielding fruit, banana cultivation generates a large amount of biomass waste such as pseudostem and leaves. Farmers commonly treat the banana pseudostem as waste and dispose of it, unaware of its potential value. Around 60 % of waste would be generated after the harvest of bananas (Patil *et al.*, 2024). The improper disposal of banana pseudostem waste can lead to serious environmental issues. A hectare of banana plantation is said to generate about 220 tonnes of biomass waste. In India, millions of tonnes of banana pseudostem are discarded as waste, causing ecological damage.

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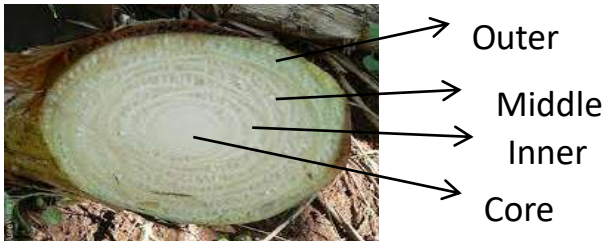


Fig 1. Structure of Banana Pseudostem

The banana pseudostem, resembling a trunk, is formed by tightly wrapped leaf sheaths around a central core (Patil *et al*., 2024). The pseudostem is a rich source of dietary fiber, vitamin B6, potassium, and also contains antioxidants like polyphenols and catechins. This pseudostem was typically left to rot or burned and contributing nothing to the farmer's income. To address this issue, several studies explored the potential of converting this abundant waste into valuable industrial products. Today, recent innovations and sustainable technologies revealed that this so-called waste is being transformed into 'green gold' through innovative applications

Banana fiber Extraction: A thriving sector

In the current scenario, global demand for natural fiber is increasing due to their biodegradable nature and renewability. Banana pseudostem is composed of cellulose, hemicellulose, and lignin and it is a rich source of natural fiber. Banana fibers are composed of lignocellulosic materials. Cellulose is the most abundant, accounting for 50-60 % of the fiber. Hemicelluloses are the second-most predominant at 25-30%, followed by lignin (12-18%) and smaller amounts of pectin, fat and wax present at 3-5 % each (Patil *et* al., 2024). Banana fiber can be extracted through mechanical, chemical or enzymatic methods and a wide range of surface modification treatments are there to modify their surface properties. These fibers are durable, renewable, and eco-friendly, making it suitable for various applications such as textiles, ropes, paper, packaging materials, sanitary napkins and as component in polymer composites used in construction, automotive, and sports equipment. Along with the major application of banana fiber mentioned, studies are undertaken for developing vegan leather, waste water treatment etc.

Banana Pseudostem Sap

Pseudostem sap is a liquid mainly extracted from the banana plant's pseudostem. Sap can be extracted from the pseudostem during fiber extraction or by crushing the pseudostem itself. While extracting fiber from the pseudostem, approximately 5000-6000 liters of pseudostem sap can be obtained per acre. This sap is nutrient rich by-product that is often considered as waste after banana harvesting. It has high chemical oxygen demand (COD) and biological oxygen demand (BOD) and if discarded as waste water, may lead to environmental issues. It's a thick liquid with clear appearance but slowly turns light khaki due to oxidation. It contains essential minerals like potassium, magnesium, calcium and sodium as well as plant growth regulators(like auxins &cytokinins), starch, proteins, vitamin C, iron and other phytocompounds. This sap can

be used as plant growth regulators, nutrient solutions to commercial crops and vegetables, biofertilizer-additive and also used as dyeing-agent and mordant in textile industry. It can be developed as mineral sap-drink due to its mineral content. Additionally, it can be harnessed to produce plant-based biochemicals which are used in various industries. Research also explores its potential as an anticorrosive agent for concrete steel and as a component in biofuel and bioethanol production (Gupta *et al*., 2019, Gupta *et al*., 2024). These applications lower the chemical load on the environment and also promote sustainable practices.

Paper and Pulp Production

In the current situation the global demand for pulp and paper is increasing rapidly. However producing pulp as well as paper from wood causes significant challenges, including deforestation and huge chemical and energy consumptions which leads to global warming and loss of biodiversity. As a sustainable alternative for paper production, lignocellulosic wastes are drawing focus due to their low cost, low energy and chemical consumption. Among them, banana pseudostem can be use for paper and pulp production and it will offer an eco-friendly and economically viable alternative to traditional wood-based pulp. After the fiber extraction, the remaining pulp from the pseudostem can be processed into paper pulp. This not only added values to the agricultural waste, but also helps in reducing deforestation and provides income opportunities for farmers.

Banana pseudostem as an Animal Feed

Banana pseudostems can be utilized as a component in animal feed, providing a way to transforming agricultural wastes into a valuable resource. Chopping the pseudostems into small pieces and mixing it with other feed components makes an effective, low-cost fodder alternative for animals. Although banana pseudostems offers nutritional benefits, particularly in fiber and minerals, it typically requires processing such as ensiling or drying and supplementation with other nutrients, particularly protein, to serve as a complete and effective feed for livestock. It has been explored as feed for various livestock, including goats, sheep, cattle, and pigs with outcomes varying based on the method of preparation and the level of nutritional supplementation. Using pseudostem as fodder **reduces the need for expensive commercial feed**, which often contains additives or imported ingredients.

Biogas and Composting Applications

Banana pseudostem waste is rich in organic matter, making it an excellent source for biogas generation. In recent years, anaerobic digestion (AD) of banana stems for methane production has substantial attention. The high moisture and nutrient content support microbial activity, which results in the production of methane-rich biogas that can be used as renewable energy source as well as sustainable waste management. This could lead to job creation, improved living standards and benefit rural communities lacking electricity ((Li *et al*., 2016). Additionally pseudostem can be used in vermicomposting, where earthworms breakdown the material into nutrient-rich compost. It is also suitable for producing organic compost through aerobic decomposition. It helps to improve soil health, water retention, increasing crop yields and leads to sustainable farming practices.

Food Products

Several food products can be developed from banana pseudostem due to its high content of bioactive components. The central core of the banana pseudostem is an edible part. About 10 to 12 tonnes/ha central core can be obtained in banana. In many parts of India, the pith or tender core is traditionally consumed as food after boiling and seasoning with spices. Banana stem can be enjoyed either cooked or raw in juice from. It is rich in fiber, helps in weight loss by promoting fullness and reducing food intake. It is having lot of health benefits (C P Ambrose, 2016). The food products can be developed from banana stem includes squash, bread, cookies, ready-to-drink juice, cutlets, juice, fortified pseudostem juice powder, isotonic drink and pickle (Pillai *et al*., 2024). Therefore, the biomass usually discarded in fields could be explored to be processed and utilized as a fiber-rich health supplement in food products.

Handicrafts and Cottage Industry Boost

The characteristics of the banana fibre like high strength, small elongation, light weight, good moisture absorption and release characteristics, natural colour, and degradable characteristics make it very suitable for product development. Many handicraft and household products like hand bags, purses, table mats, mobile cover, CD pouches, net bags, ornamental covers, door mats, curtains, file covers are made from banana fibre. It can provide employment generation to rural sector, particularly women and also encourages rural entrepreneurship.

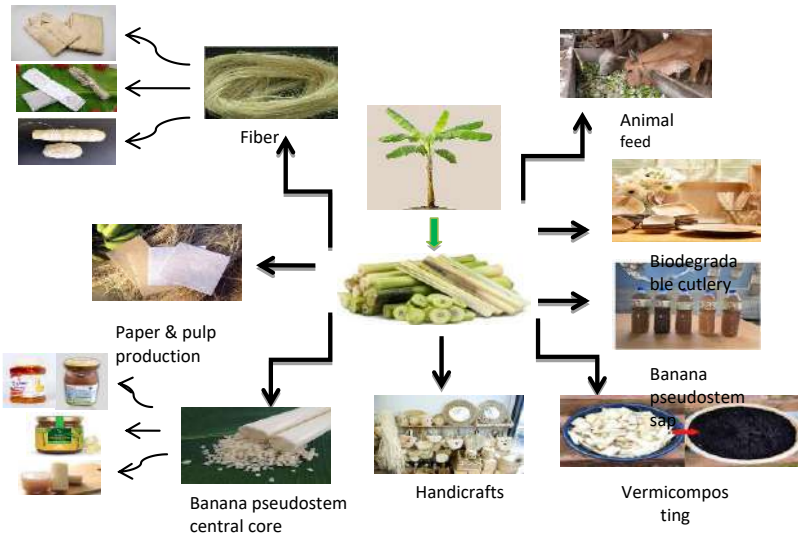


Fig 2. Banana pseudostem uses

Other Applications

The scutcher waste obtained after fiber extraction from pseudostem can be processed into biodegradable cutlery using suitable binding materials. Along with the major applications of banana pseudostem mentioned above, studies are undertaken for developing Xylitol extraction from banana pseudostem scutcher waste, formulation of nutrient-enriched banana stem juice with various components, extraction of compounds from banana pseudostem which can aid wound healing, composite hydrogel development from banana pseudostem for efficient dye removal and multifunctional carbon dots from banana. Additionally, developed nanocellulose based bioplastic from banana pseudostem juice (Faradilla *et al*., 2022), eco-friendly biofilms by utilizing microcrystalline cellulose extract from banana pseudostem (Sachcha *et al*., 2024), thermally stable cellulosic substrate from banana pseudostem sap (Basak *et al*., 2016).

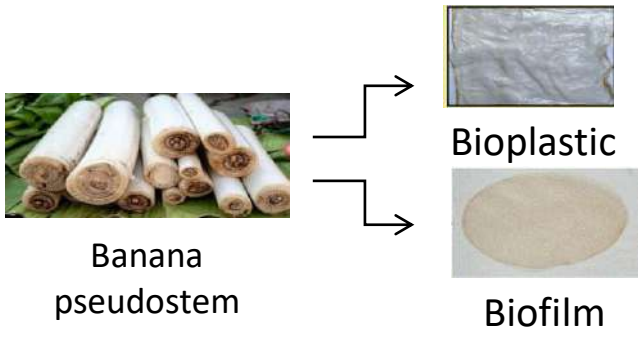


Fig 3. Other applications of Banana pseudostem

Conclusion

Traditionally, the banana pseudostem was discarded as agricultural waste after harvesting. But now, with increased awareness and advanced processing technology development, it is being recognized as useful raw material. Because of its high nutritional content and fiber content, the pseudostem has numerous applications across various industries like textiles, food, packaging, animal feed, handicrafts and bio-based products. By adopting appropriate machineries for fiber extraction, sap collection, further processing and understanding market opportunities farmers can commercialize what was once a waste product. This development not only provides an additional income to farmers, but also promotes zero-waste farming, sustainable agricultural practices, and employment generation for women which makes banana pseudostem a true example of 'green gold'.

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BOKASHI COMPOSTING

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Introduction

Bokashi composting is an anaerobic fermentation process that relies on inoculated bran to ferment kitchen waste, including meat and dairy, into a safe soil builder and nutrient rich tea for your plants. Bokashi is a composting method of fermentation that you can easily do at home with just a few simple steps that involve sealing kitchen scraps and organic waste in an airtight container with a medium. The finished product is an extremely nutrient-dense plant food that may be buried in compost trenches in a garden. It is an anaerobic fermentation process that relies on inoculated Bokashi bran to ferment kitchen waste, including meat and dairy, into a safe soil builder and nutrient-rich tea for your plants.



In Bokashi composting, food scraps of all kinds including those that are banned from traditional composting methods like meat, and dairy products are mixed with some of the inoculated bran, pressed into the Bokashi bucket, covered with another handful of bran, and tightly covered. When the bucket is full, it is sealed shut and set aside for ten to twelve day.

Every other day during that time, you can use the handy spigot in the Bokashi bucket to drain the liquid which is an inevitable byproduct of this composting process. This liquid is also known as 'Bokashi tea' and is an invaluable asset for your houseplants since it's packed with nutrients

Bokashi is a Japanese word meaning "fermented organic matter." Developed in the early 1980s by Dr. Teuro Higa, a professor at the University of the Ryukyus, Okinawa, Japan, the method involves layering kitchen scraps (vegetables and fruits, as well as meat and dairy scraps) with a bokashi inoculant in a special bucket. Usually, the inoculant consists of either wheat germ, wheat bran, or sawdust combined with molasses and effective microorganisms (EM). The bran/molasses serve as the food for the microorganisms, which are the same natural microorganisms found in soil.

Composting Process

- Perhaps once a day you mix your kitchen waste (including meats and dairy products!) with a layer of Bokashi bran (basically enough to coat it lightly), then press it into the bin, sprinkle bran over them, and close the lid.
- Place a plate or a layer of plastic over the pile to help seal it against the little air left in the bucket. Large bones will not, of course, disappear over the course of ten days
- It's recommended to cut up small bones and even chop other items into small pieces for maximum efficiency.
- If one chose to skip the chopping step, a few extra days' fermentation time would probably reduce the larger pieces to thoroughly fermented mush. You should add up to 2 tablespoons of bokashi bran for every couple of inches of food waste until the bin is full.
- When the bin is full, cover it tightly and set it aside somewhere in the house where it's out of direct sunlight for ten days or so. Every other day, draw off the liquid (bokashi tea), which can be used as a fertilizer (in a very diluted form) or full strength to control slime in drains, pipes, and septic systems
- After ten to fourteen days, the waste in the tub should be pickled thoroughly. It can then be dug into a fallow patch of the garden





Bokashi Composting vs. Traditional Composting

Unlike traditional composting, which is an aerobic process that requires oxygen, bokashi is an anaerobic process that requires that you isolate the materials from oxygen as much as possible. The recipe for traditional composting is a mixture of green materials high in nitrogen, brown materials high in carbon, and air and water. The bokashi process is a fermentation process rather than a traditional composting method. A big difference between bokashi and traditional composting is that you are less restricted in what you can compost. Any food waste, including dairy and meat, is fair game. However, bokashi compost bins have more space limitations than traditional compost bins. Because bokashi compost bins are usually small and used indoors, there is no room for garden waste, such as grass clippings.

Ways to Use Bokashi Compost

The end product of bokashi composting is different from traditional composting which is ready to be used in the garden as it is with a pH between 4.0 and 5.0 (or even lower depending on what went into the bin), both bokashi tea and pre-compost are quite acidic. Bokashi tea cannot be used as a fertilizer on houseplants or garden plants directly, it needs to be diluted first at a rate of about 1:100. Add 1 tablespoon of bokashi tea to 6 ¼ cups of water. For acid-loving plants, such as azaleas, use slightly less diluted water of about 1:80.Add the bokashi pre-compost to a traditional compost pile, large planters, or garden soil.1 Because of its high acidity, distribute the pre-compost as evenly as possible to avoid it being concentrated in one spot. It takes about two weeks for the bokashi pre-compost to be absorbed by the soil web, and about a week longer in cold weather. If you want to use bokashi compost for your lawn, safely mix it with other compost before spreading it.



Pros:

- ✓ It lets you use dairy and meat scraps that are not incorporated in other forms of composting.
- ✓ Bokashi composting requires a relatively small space.
- ✓ The resulting product makes a highly nutritious pre-compost for burying in garden compost trenches.

Cons:

- ✓ The pre-compost must either be buried in garden trenches or added to a traditional compost heap for further breakdown.
- ✓ The process requires a special airtight bucket or bin with the ability to drain off the liquid that is produced.
- ✓ Both the bokashi tea and the pre-compost are highly acidic.

Conclusion

Bokashi is essentially a system that pickles your food waste before it turns into nutritious liquid compost ready to put back into the garden soil. To start with Bokashi you'll need a medium. The Bokashi host medium can be almost any fine organic grain or grass-like substance — bran, rice, wheat mill run (WMR, a waste product from flour milling), used mushroom growth medium, dried leaves, or even sawdust. They're all added to your Bokashi bucket that comes with a spigot to drain the liquid that occurs due to this anaerobic composting process. Unlike traditional composting, which is an aerobic process that requires oxygen for the composting process to work, Bokashi is an anaerobic process that requires isolating the materials

as much as possible from oxygen. This means the bucket should only be opened to add scraps, not to inspect the contents regularly.

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NUTRITIONAL EPIGENETICS IN AQUACULTURE: DIET DRIVEN GENE EXPRESSION AND TRANSGENERATIONAL EFFECTS

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Abstract

Fish don't just respond to what they eat — their genes do too. In recent years, researchers have discovered that the nutrients in a fish's diet can actually influence which genes are turned on or off, thanks to a fascinating biological process called epigenetics. This means that feed doesn't just fuel fish growth and health in the short term; it can also shape their genetic activity in ways that last a lifetime — and even affect the next generation. This emerging field of nutritional epigenetics in aquaculture explores how ingredients like vitamins, fatty acids, and plant compounds interact with fish DNA, influencing everything from immunity and metabolism to stress tolerance and reproductive success. Intriguingly, these effects can be passed from broodstock to offspring, opening up possibilities for diet-based "programming" of better-performing fish. This article takes a closer look at how feed drives gene expression, the science behind epigenetic inheritance in aquatic species, and how this knowledge could revolutionize fish farming for future generations.

Introduction

Aquaculture is rapidly expanding to meet the growing global demand for seafood, requiring innovations that go beyond traditional feeding practices. Nutritional epigenetics is an exciting new field that studies how diet can influence gene expression without altering the underlying DNA sequence (Bird, 2007). Through mechanisms like DNA methylation and histone modification, nutrients can act as molecular switches that turn genes on or off, affecting important traits such as growth, immunity, and metabolism (Feil & Fraga, 2012). Importantly,

these epigenetic changes can sometimes be inherited, meaning that what fish eat today could impact not only their health but also that of their offspring. Understanding these processes offers great potential to improve fish performance and disease resistance through smarter feeding strategies. This emerging knowledge is poised to transform aquaculture by integrating genetics, nutrition, and environmental management. However, much remains to be explored, especially across diverse aquaculture species. This article explores how diet acts as an epigenetic modifier and its implications for sustainable fish farming.

What is Epigenetics?

Epigenetics refers to **heritable changes in gene activity or expression that do not involve changes to the underlying DNA sequence itself**. In simpler terms, it's like a set of biological instructions that tell the cell which genes to turn on or off, and when to do so, without rewriting the genetic code. These instructions can be influenced by various environmental factors, including diet, stress, and pollutants, allowing organisms to adapt dynamically to their surroundings.

There are three primary mechanisms through which epigenetic regulation occurs:

DNA Methylation: This involves the addition of small chemical groups called methyl groups ($-CH_3$) to specific sites on the DNA, usually at cytosine bases near gene regions. Nutrients such as folate, vitamin B12, and choline serve as important methyl donors in this process. When methyl groups attach to DNA, they can silence genes by preventing the cellular machinery from accessing and reading them, or conversely, they can activate genes depending on the location of methylation. This process plays a critical role in regulating gene activity during development and in response to dietary inputs.

Histone Modification: DNA is tightly wound around proteins called histones, which help package the genetic material inside the cell nucleus. Chemical modifications of histones—such as acetylation, methylation, or phosphorylation—can alter how tightly or loosely the DNA is wrapped. When histones are modified, the structure of chromatin (the complex of DNA and protein) changes, making certain genes more or less accessible for transcription. For example, acetylation of histones generally loosens DNA packaging, allowing genes to be expressed more readily.

Non-coding RNAs: These are RNA molecules that do not code for proteins but have regulatory roles in gene expression. MicroRNAs (miRNAs), a type of non-coding RNA, bind to messenger

RNAs and can prevent them from being translated into proteins. This post-transcriptional regulation fine-tunes gene expression and can be influenced by nutritional status, impacting processes like immune response and metabolism.

Together, these epigenetic mechanisms create a complex regulatory network that enables fish—and other organisms—to respond flexibly to dietary and environmental signals, shaping physiological outcomes without changing the genetic blueprint itself.

3. Diet as an Epigenetic Modifier in Fish

Diet plays a crucial role in shaping the epigenetic landscape of fish by providing specific nutrients and bioactive compounds that influence gene expression through various molecular mechanisms. These dietary factors can either directly participate in epigenetic processes or indirectly affect the enzymes and pathways responsible for modifying gene activity.

3.1 Methyl-Donor Nutrients

Certain nutrients act as **methyl donors**—molecules that supply methyl groups essential for DNA methylation, a key epigenetic modification. Nutrients such as **methionine**, **choline**, **folate**, and **vitamin B12** are fundamental in maintaining adequate methylation patterns. These compounds enter the one-carbon metabolism cycle, which generates S-adenosylmethionine (SAM), the universal methyl group donor for DNA and histone methylation reactions.

When fish diets lack sufficient methyl donors, this can lead to **hypomethylation**—a reduction in methyl groups attached to DNA—which may cause abnormal gene activation or silencing. Such epigenetic changes can affect critical genes involved in **growth regulation, lipid metabolism, and stress response**, ultimately impairing fish health and productivity. Conversely, diets enriched with methyl donors can promote stable and beneficial methylation patterns, supporting optimal gene function and fish performance.

3.2 Polyphenols and Functional Additives

Polyphenols and other plant-derived bioactive compounds present in functional feeds are emerging as important **epigenetic modulators**. Natural substances like **resveratrol** (found in grapes), **curcumin** (from turmeric), and **butyrate** (a short-chain fatty acid produced by gut microbiota) have demonstrated the ability to influence histone modifications, particularly **histone acetylation**.

Histone acetylation generally relaxes chromatin structure, increasing gene accessibility and expression. Polyphenols can modulate the activity of enzymes called histone acetyltransferases

(HATs) and histone deacetylases (HDACs), balancing gene expression involved in **inflammation, oxidative stress, and immune responses**. For example, butyrate acts as an HDAC inhibitor, promoting the expression of anti-inflammatory genes, which can enhance disease resistance in fish.

3.3 Omega-3 Fatty Acids

Long-chain polyunsaturated fatty acids (PUFAs), particularly **eicosapentaenoic acid (EPA)** and **docosahexaenoic acid (DHA)**, are well known for their health benefits. Beyond their nutritional value, these omega-3 fatty acids influence gene expression through interaction with **nuclear receptors**, such as **peroxisome proliferator-activated receptors (PPARs)**, which regulate genes involved in lipid metabolism, inflammation, and energy homeostasis.

Moreover, omega-3 PUFAs may impact epigenetic marks by modifying DNA methylation and histone acetylation patterns. These fatty acids can help maintain balanced gene regulation, supporting metabolic efficiency and reducing chronic inflammation, which is vital for optimal growth and stress resilience in farmed fish.

4. Evidence from Aquatic Species

4.1 Zebrafish as a Model

Zebrafish (*Danio rerio*) have become a widely used model organism to study nutritional epigenetics due to their well-characterized genome and ease of experimental manipulation. Research indicates that **maternal diet composition**, such as a high-fat versus a balanced diet, can significantly alter gene expression patterns in offspring, impacting growth and metabolic functions (Andersen et al., 2020). Specifically, supplementation of methyl-donor nutrients like folate and methionine in the maternal diet was shown to modify **liver DNA methylation profiles** in zebrafish offspring, demonstrating that dietary components can directly influence epigenetic marks during early development (Andersen et al., 2020).

4.2 Salmonids and Epigenetic Memory

In salmonids, including Atlantic salmon (*Salmo salar*), broodstock nutrition has been linked to epigenetic modifications that affect gene expression in offspring related to **immune function** and **muscle development** (Skugor et al., 2016). These changes are believed to occur through epigenetic remodeling in the germ cells—both sperm and eggs—resulting in heritable differences in progeny phenotype (Le Luyer et al., 2017). This "epigenetic memory" allows

parental diets to shape the resilience and growth potential of the next generation, offering aquaculture opportunities for targeted nutritional programming of broodstock.

4.3 Nile Tilapia and Early Life Programming

In Nile tilapia (*Oreochromis niloticus*), early life-stage nutritional interventions, such as the inclusion of immunostimulants or essential micronutrients, have been shown to induce long-lasting phenotypic changes. These include enhanced disease resistance and improved growth performance that persist into adulthood (Panserat et al., 2017). Such **nutritional programming** during critical windows of development highlights the potential for feed formulations to epigenetically shape lifelong traits in commercially important species.

5. Transgenerational Epigenetic Effects

Epigenetic modifications that occur in **germline cells**—the sperm and eggs—can be inherited by progeny, enabling **transgenerational epigenetic inheritance** (Heard & Martienssen, 2014). This phenomenon is gaining increasing attention in aquaculture as it suggests that diets not only affect the fish being fed but can influence the **performance, health, and adaptability of future generations**.

For aquaculture, this opens exciting possibilities: designing broodstock diets that induce beneficial epigenetic marks may enhance traits such as **feed efficiency, stress tolerance, and disease resistance** in offspring without genetic modification (Andersen et al., 2020; Skugor et al., 2016). Such strategies could lead to more sustainable and resilient production systems, reducing reliance on chemicals and antibiotics.

6. Applications and Future Perspectives

Application Area	**Nutritional Epigenetics Role**
Broodstock Nutrition	Optimizing reproductive gene expression and offspring robustness
Sustainable Feed Formulation	Balancing plant-based diets to avoid undesirable epigenetic silencing
Selective Breeding	Identifying epigenetic markers for high-performing lines
Climate Resilience	Programming stress-responsive genes via early-life nutrition

- ✓ Development of **epigenetic biomarkers** to guide feed formulation.
- ✓ Potential integration with **CRISPR** and **genomic selection tools** in aquaculture breeding.

7. Challenges and Research Gaps

Despite the promising potential of nutritional epigenetics in aquaculture, several significant challenges and knowledge gaps remain, which must be addressed to fully harness this field.

A major limitation is the **lack of long-term and multi-generational studies**, especially in commercially important but non-model fish species. Most current research relies heavily on model organisms such as zebrafish (*Danio rerio*) and a few salmonid species, which limits the generalizability of findings across diverse aquaculture species with different life histories and environmental conditions (Andersen, Rasinger, & Eilertsen, 2020). Longitudinal studies that track epigenetic modifications and phenotypic outcomes over multiple generations are essential to understand the stability and heritability of diet-induced epigenetic changes (Heard & Martienssen, 2014).

Additionally, the field lacks **species-specific epigenetic reference maps and validated biomarkers**. Epigenomes can vary widely between species and even populations, making it challenging to interpret methylation patterns or histone modifications without a robust baseline (Gavery & Roberts, 2017). Developing detailed epigenetic atlases for key aquaculture species will enable more precise identification of epigenetic marks linked to desirable traits such as growth, immune response, or stress tolerance.

Another critical area involves **ethical and regulatory considerations** surrounding the manipulation of heritable gene expression through nutrition or other environmental factors. Unlike genetic modification, epigenetic changes are reversible and environmentally influenced, but their transgenerational transmission raises questions about unintended consequences, biodiversity, and animal welfare (Panserat et al., 2017). Regulatory frameworks for epigenetic interventions in aquaculture are currently lacking, and guidelines must be developed to ensure responsible use.

Finally, the complexity of epigenetic mechanisms demands interdisciplinary research combining **-omics technologies, bioinformatics, nutrition, and fish physiology** to unravel how diet interacts with the epigenome in real-world aquaculture settings (Skugor et al., 2016).

Addressing these challenges will pave the way for practical applications of nutritional epigenetics that are both effective and ethically sound.

Conclusion

Nutritional epigenetics is opening new doors in aquaculture by showing how diet can shape fish health and growth beyond just basic nutrition. By influencing gene activity without changing DNA, feed can improve not only the current generation but also future offspring. This means smarter feeding strategies could help produce stronger, more resilient fish. However, more research is needed, especially in diverse fish species, to fully understand these effects. Ethical considerations also play a role as we learn to manage heritable changes responsibly. Overall, combining nutrition and epigenetics holds great promise for sustainable and efficient aquaculture. It's an exciting field that could transform how we raise fish for years to come.

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HARNESSING INDIGENOUS TECHNICAL KNOWLEDGE FOR SUSTAINABLE AGRICULTURE IN ASSAM

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Abstract

Integration of Indigenous Technical Knowledge (ITK) into agricultural practices has emerged as a pivotal strategy in the face of increasing climate change to improve crop resilience and ensure sustainable farming. The paper focuses on ITKs followed in Assam, a northeastern state famous for its mega biodiversity and indigenous farming traditions. Farmers in Assam have been using ITKs conventionally in adapting to climatic variability, efficient water management, reducing pest attack and soil fertility management etc. The introduction highlights the vulnerabilities of agriculture to climate variability and emphasizes the significance of ITK in fostering sustainability. A review of literature underscores ITK's role in enhancing soil health, managing pests, and conserving biodiversity while mitigating environmental impacts. Objectives include documenting ITKs practiced in Assam and evaluating their contributions to climate resilience and sustainable agriculture. The methodology involved secondary data collection and participatory tools like transect walks, resulting in the documentation of 30 ITKs used in cereal, fruit, and vegetable cultivation, as well as pest management. Results revealed ITK practices such as using neem leaves for pest control, composting for soil fertility, and traditional irrigation techniques that enhance adaptability to climate-related adversities like floods and droughts. These methods not only promote ecological balance but also reduce dependence on chemical

inputs, thus supporting long-term agricultural productivity and environmental health. The conclusion advocates for integrating ITK with modern agricultural frameworks to develop location-specific, eco-friendly, and economically viable solutions. It underscores the potential of ITK to transform agricultural systems, enhance community resilience, and serve as a model for global sustainability efforts. The study emphasizes creating awareness and preserving these traditional practices to address the dual challenges of climate change and sustainable development. The paper, therefore, advocates for an inclusive agricultural strategy as one paradigm shift by underlining how ITK may play its mitigating role in those aspects ofclimate change'simpact. Its integration would therefore go to help not just the farmers in Assam themselves but also be a relevant model to foster resilience at a time when world agriculture faces the ongoing climate crisis.

Keywords: Assam, Climate Resilient Agriculture, ITK, Sustainability

Introduction

The escalating threats posed by climate change have shifted the global focus toward sustainable and resilient agricultural practices. Agriculture, being highly dependent on weather and climatic patterns, is especially vulnerable to irregular rainfall, extreme temperatures, and natural disasters. These challenges not only threaten food security and rural livelihoods but also disturb the ecological balance, particularly in areas where traditional farming methods are still practiced. In this context, Indigenous Technical Knowledge (ITK) has emerged as a valuable tool for addressing the impacts of climate change. It represents the traditional knowledge, skills, and practices of local communities that have evolved over generations to sustainably manage natural resources and farming systems.Historically, chemical pesticides have been used extensively in agriculture since the 1800s, starting with arsenical insecticides and Bordeaux mixture. Though these chemicals provided quick relief from pests and diseases, their prolonged use has led to serious environmental and health consequences. There is now strong evidence that many chemical pesticides pose significant risks to humans, animals, biodiversity, and soil health (Boruah et al., 2020; Rana et al., 2018). In contrast, ITK offers eco-friendly and cost-effective alternatives that have long supported sustainable agriculture without causing harm to the environment.

ITK includes a wide range of practices such as crop rotation, intercropping, agroforestry, organic pest control, and indigenous weather prediction. These methods reflect a deep

understanding of local ecosystems and have proven effective in maintaining soil fertility, controlling pests naturally, and reducing dependency on external inputs. Such practices are especially useful in resource-poor farming communities, where modern inputs are either too costly or unavailable. Despite the progress in scientific research, ITK remains relevant and is still widely used by farmers—often without awareness of the scientific rationale behind them (Singh et al., 2020). Therefore, documenting and validating these practices is essential for their preservation and integration into modern farming systems.

Assam, a biodiversity-rich state in Northeast India, provides a compelling example of how ITK contributes to climate-resilient agriculture. The region is part of one of India's two biodiversity hotspots and is home to numerous ethnic communities such as the Ahom , Mishing , Deori , and Karbi , each with their own unique agricultural traditions. These communities have developed climate-specific practices, such as using neem and other plants for pest control, adopting flood-resistant crop varieties, and constructing traditional irrigation systems suited to local topography (Boruah et al., 2020; Deka et al., 2023). These practices not only ensure productivity but also help farmers cope with the impacts of floods, droughts, and other climatic uncertainties.

Sustainable agriculture emphasizes minimizing chemical use, improving soil health, protecting biodiversity, and ensuring long-term viability for farmers. Practices like Integrated Pest Management (IPM), agroforestry, and reduced tillage align well with ITK-based approaches. When combined with modern scientific techniques, these traditional practices offer context-specific, adaptive solutions that enhance both productivity and resilience. Climate resilience in agriculture refers to the capacity to prepare for, adapt to, and recover from climatic shocks while maintaining stable agricultural output. In Assam, ITK-based strategies such as crop diversification and local weather forecasting have significantly contributed to the resilience of farming communities.

The integration of Indigenous Technical Knowledge with modern agricultural frameworks holds great promise for addressing the dual challenges of climate change and sustainability. Assam's example shows how local wisdom, when scientifically supported and properly documented, can strengthen farming systems and offer replicable models for other vulnerable regions. Promoting ITK is not just about preserving tradition—it is about building a more resilient and sustainable future for agriculture.

METHODOLOGY

The ITKs in relation to sustainable development in Agriculture were collected using both primary and secondary sources. A multistage random sampling technique was used to collect data with structured scheduled and personal interview across Assam..The Participatory Rural Appraisal (PRA) tools like transect walk and timeline methods were employed to follow up the ITKs. A total of thirty numbers of ITKs were documented in relation to their practice in cereal crops, fruit and vegetable cultivation and to control storage pests. Secondary data were collected from published research paper which are included in the reference section.

RESULTS AND DISCUSSION

The agricultural landscape of Assam, a northeastern state of India, is deeply rooted in rich traditional knowledge and cultural practices. Farmers in this region somehow depend on **Indigenous Technical Knowledge (ITK)** to tackle various agricultural challenges such as managing soil fertility, controlling pests and diseases, ensuring crop diversification, and conserving water. These traditional practices include methods like composting and green manuring for soil enrichment, as well as agroforestry systems that combine trees, shrubs, and crops to optimize resource utilization and promote ecological sustainability. Such practices support crop diversification and help farmers adapt to changing environmental conditions.Findings from the study reveal that farmers in Assam have long employed a variety of indigenous methods to control pests and diseases affecting cereals, vegetables, fruits, and storage crops—all aimed at ensuring long-term resource sustainability. Some commonly practiced traditional techniques in Assam include clipping the tips of rice (Oryza sativa) seedlings before transplanting, lighting torches in rice fields during the milky stage in the evening, applying goat dung to fields, spraying crops with cow urine, using neem leaves and seeds, applying *fut chai* (wood ash), using smoke to repel fruit flies, and painting citrus tree trunks with lime. These time-tested techniques reflect the community's deep understanding of local ecology and their efforts to maintain sustainable agriculture.

The study highlighted several Indigenous Technical Knowledge (ITK) practices used by farmers, particularly in rice (Oryza sativa) cultivation, to manage pests and improve crop health. During the milky stage of rice—a period marked by a high incidence of the Gundhi bug (*Leptocorisa acuta*)—farmers light flames in the field to repel the pest. Goat droppings are applied not only as an organic manure but also as a pest deterrent. Another common practice

involves clipping the tips of rice seedlings before transplanting, which helps in controlling the rice hispa (*Dicladispa armigera*). Additionally, placing the head of a dead frog in rice fields is believed to attract and trap pests like the Gundhi bug, drawn by the decomposing odor. Rice-fish farming is also widely practiced to enhance sustainability and pest control.In vegetable cultivation, similar low-cost and eco-friendly methods are adopted. For instance, wood ash is sprinkled over crops such as brinjal (*Solanum melongena*) to manage aphids (*Aphis gossypii*) and other harmful insects. Likewise, pieces of black tobacco (*Nicotiana tabacum*) leaves are placed in cabbage (*Brassica oleracea*) fields to prevent diseases and repel insects. These practices are especially common among rice growers, who rely on easily available and cost-effective resources.

Each of these ITKs contributes individually towards climate resilience and sustainable agriculture. Farmers in Assam have traditionally employed several indigenous practices for pest and disease management is used in horticultural crops. One such method includes **smoking under mango trees (*Mangifera indica)* during the flowering stage** to repel harmful insects like the **stone borer (*Sternochetus mangiferae*)** and **mango mealy bug (*Rastrococcus invadens*).** Another widely followed practice is the **decomposition of banana pseudostems (*Musaacuminata*) in the field**, which helps in managing pests and diseases by improving soil health and disrupting pest life cycles. Additionally, **placing fish waste beneath citrus plants**as a strategy to**attract fruit-sucking moths (*Othreis fullonia*),** diverting them away from the main crop and thereby reducing fruit damage. These eco-friendly techniques reflect the deep ecological understanding of local farming communities and their efforts to maintain crop health through sustainable and cost-effective means.Farmers in Assam have long relied on Indigenous Technical Knowledge (ITK) for managing storage pests through simple and effective methods. One common practice involves **mixing ash with seeds before storage,** which helps in **preventing infestation by storage pests**. Another widely used technique is **placing neem (Azadirachta indica) leaves inside rice storage structures**, as neem possesses natural insect-repellent properties and **is highly effective against storage pests**. Additionally, **covering stored potatoes with a layer of sand** serves as a **physical barrier to control pests,** protecting the tubers from damage. These traditional practices are eco-friendly, low-cost, and continue to play a vital role in preserving the quality and shelf-life of stored agricultural produce. These techniques use a simple, non-chemical method to manage pests, reducing dependency on synthetic

pesticides. By reducing pesticide usage, this practice supports soil health, water quality, and biodiversity, essential for sustainable farming.Goat manure improves soil organic matter and enhances the soil's water retention capacity, which is critical in coping with irregular rainfall and drought conditions. It enriches the soil with nutrients, promotes healthy microbial activity, and reduces reliance on synthetic fertilizers, lowering greenhouse gas emissions from fertilizer production. Indigenous technical knowledge (ITK) practiced by farmers plays a vital role in addressing the challenges posed by climate change and promoting sustainable agriculture. Due to their low-cost nature, ITKs not only support environmental sustainability but also contribute positively to the national economy.

In recent years, the ecological value and long-standing benefits of these traditional practices have begun to gain recognition. However, there is a pressing need to raise awareness among farming communities to ensure the preservation of ITKs and to prevent their gradual disappearance. The effectiveness of Indigenous Technical Knowledge (ITK) practices in agriculture is demonstrated by their ability to enhance soil health, increase crop yields, and bolster resilience against climatic variability. Farmers consistently affirm the success of traditional methods such as mixed cropping, intercropping, and crop rotation in mitigating pest and disease outbreaks while reducing reliance on external inputs. Recognizing the importance of ITK is crucial for advancing sustainable development, preserving cultural heritage, and strengthening community resilience.

Conclusion

The application of Indigenous Technical Knowledge (ITK) in agriculture by farmers in Assam highlights the deep interconnection between cultural traditions, the environment, and rural livelihoods. These time-tested knowledge systems offer valuable insights and practical approaches to address contemporary agricultural challenges, forming a strong base for advancing sustainable development and climate resilience. To protect and promote these practices, future initiatives should be rooted in principles of equity, inclusivity, and respect for indigenous rights. Valuing the diversity of knowledge systems and encouraging collaborative engagement among farmers, researchers, policymakers, and other stakeholders can help build resilient agricultural models that secure food systems, conserve the environment, and preserve cultural identity for future generations.Incorporating ITKs into agricultural extension services, scientific research, and policy-making can significantly improve the relevance and effectiveness of agricultural

development efforts. Documented indigenous practices can provide a valuable resource for scientists seeking to assess their scientific validity and effectiveness. This documentation can also support the blending of traditional and modern technologies to develop eco-friendly, cost-effective, location-specific, and socially acceptable agricultural innovations (Barman et al., 2012).Furthermore, empowering local communities to document, revitalize, and share their traditional knowledge not only helps conserve biological diversity but also strengthens agroecological systems and supports adaptation to climate change. By recognizing and utilizing the collective wisdom of indigenous communities, decision-makers, researchers, and practitioners can co-create innovative, context-sensitive solutions to the complex challenges facing agriculture today.

These recorded ITKs will serve as essential references for designing technology-blending programs aimed at generating low-cost, environmentally sustainable, and locally adapted farming solutions. Such initiatives have the potential to benefit farmers significantly and promote long-term agricultural sustainability. However, despite their relevance, many farmers in Assam are not adopting these practices due to limited awareness and promotion. Therefore, there is an urgent need to integrate ITKs with modern sustainable practices to ensure their preservation, wider adoption, and relevance for the future.

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NUTRITIONAL PROPERTIES AND APPLICATIONS OF TAMARIND KERNEL POWDER (TKP) IN FOOD INDUSTRY

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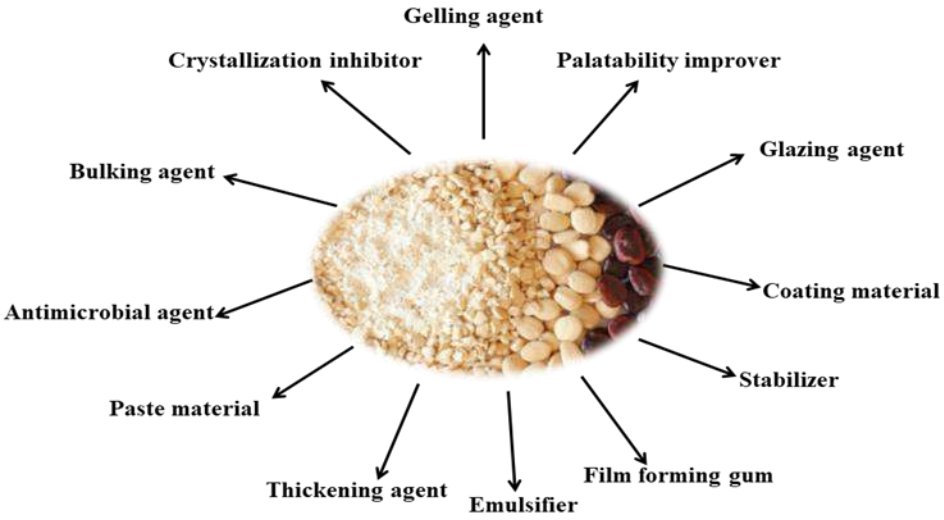
Introduction

Tamarind, botanically called as *Tamarindus indica* is a long lived, slow growing, evergreen tree belonging to the Fabaceae (Leguminasiae) family. Tamarind is a multipurpose plant.The pulp of the fruit has been used as a spice in Asian cusine, especially in southern part of India,for a long time. Almost all parts of the tree find a use in the food, chemical, pharmaceutical or textile industries, or as fodder, timber and fuel (Dagar *et al.*, 1995; George and Rao, 1997; Rao and Mary, 2001; Pugalenthi *et al*., 2004).

Tamarind seed used to be an under-utilized by-product of the tamarind pulp industry. Tamarind seeds are reported to give amber-coloured oil, free of smell and sweet to taste, which resembles linseed oil. It is rich in protein; containing high amount of essential amino acids, like isoleucine, leucine,lysine, histidine, methionine, phenylalanine, threonine, tryptophan and valine.In addition to this non-essential amino acids such as cysteine, tyrosine, arginine, alanine, aspartic, glutamic, glycine, proline and serine (de Lumen et al.1986).It is a good source of essential fatty acids and minerals particularly calcium, phosphorous and potassium.

APPLICATIONS OF TAMARIND KERNEL POWDER IN FOOD INDUSTRY

Tamarind xyloglucan imparted more viscous, liquid-like rheological properties and heat stability to gelatinized tapioca starch/xyloglucan mixtures (Pongsawatmanit *et al*., 2006). TKP is commercially available as a food additive for improving the viscosity and texture of processed foods. Its use in the preparation of bread and biscuits is also reported.



Gelling agent: Puddings, desserts, confectionery, sour milk gel, low water releasing gel,yoghurt, heat reversible gelling agents.

Thickening agent: Jams, pie fillings, sauces, viscous seasoning fluid, contrast medium, vegetable pancake, galactoxyloglucan preparation, protein free foods, acidic protein foods, vegetable dressing.

Emulsifier: Salad dressing, essential oils, in heat resistant low acid emulsion foods.

Stabilizer: Skim milk, butter, instant coffee, glucose fructose syrup, mayonnaise, cheese, emulsions, stabilize laccase activity, seasoning powder.

Bulking agent: Baked goods, puddings, creams and custard, jams, jellies, sweetened beverages, sauces, salad dressings, ice-cream, ice candy.

Crystallization inhibitor: Ice-cream, frozen foods, soya bean tofu, fried frozen food, sterilized and frozen albumen, freeze dried gel, frozen grated yam, frozen boiled noodles, frozen food covered with jelly.

Coating material: Sausage casings, protective coatings, storage of pineapple, fried foods.

Film forming gum: Extension of shelf-life of fish, pineapple.

Palatability improver: Instant noodles.

Tamarind polysaccharides are not affected by boiling in neutral aqueous solutions, even if boiled for long periods but fruit pectins undergo degradation on boiling and fall to one third of the original value after one hour of boiling. Therefore, tamarind polysaccharide can be useful as a gel forming agent, and may be substituted for fruit pectin (Kumar and Bhattacharya,2008). Unlike fruit pectin, tamarind seed polysaccharide can form gels over a wide

range of pH, including neutral and basic conditions. Low cost TKP, with a jelly grade of 80 and 85, could be used as a substitute for costly pectin for making jellies, jams and marmalades. It can form a gel which is mainly used as a thickening and stabilizing agent in the food industry.

Currently, purified refined TKP is produced and is permitted in Japan by the trade name of "Glyloid" as a thickening, stabilizing, and gelling agent in the food industry. It is reported to possess properties like high viscosity, broad pH tolerance and adhesivity and so be used in soups, sauces, jams etc.In desserts and soybean curd as water binding agent, in cakes as bulking agent, in skim milk and butter as stabilizer, in water treatment as a coagulant and in many food items as dehydrating agent, preservative, glazing agent, disperser, gelling agent and as an emulsifier.

Tamarind decorticated seed kernels contains 46 to 48 percent of a gel forming substance. Tamarind seed polysaccharide is termed as "jellose" or "polyose" and is found to be superior to other methods of fruit preservation. Jellose is much cheaper than corn starch and is required only in smaller quantities (Gunasena and Hughes, 2000). Jellose may be used for the preparation of confectionery products, salad dressings like mayonnaise-frozen desserts such as ice cream and ice milk (Vinod, 1997).

The increasing demand for continuous improvement in nutritional and functional properties of protein has contributed to the diversion of the research work from conventional sources to unconventional plant-derived protein (Henry and Kettlewell 1996).Tamarind seed protein is one such promising un-conventional protein source having potential applications in both food and pharmaceutical industries and could be explored more for further usage.

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SIGNIFICANCE OF NEXT-GENERATION FEEDS AND FEED ADDITIVES: IMPROVING POULTRY HEALTH AND PRODUCTION IN PRESENT SCENARIO

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Introduction

The poultry industry plays a pivotal role in global food security by supplying affordable animal protein in the form of meat and eggs. Thus, poultry farming is one of the most efficient animal protein production systems in the world. It supports millions of livelihoods, particularly in low- and middle-income countries. However, modern poultry production faces unprecedented challenges including climate change, antibiotic resistance, disease outbreaks, feed resource scarcity and rising production costs. To address these issues and sustain poultry productivity and health, the integration of next-generation feeds and feed additives is imperative. However, the poultry sector is increasingly pressured by factors such as: Climate variability, high feed costs, antibiotic resistance concerns, emerging diseases (e.g., avian influenza) and consumer demand for chemical-free, high-quality animal origin food products (meat and eggs).

At the heart of these challenges is feed which constitutes 65-75% of total poultry production costs. Traditional feed formulations, while functional, often fall short in terms of optimizing nutrient absorption, reducing disease risk and supporting gut health especially under current environmental stresses. This has led to the development and implementation of next-generation feeds and feed additives, which offer a more targeted, sustainable and performance-enhancing approach to poultry nutrition. This paper explores the significance of these innovations, their role in improving poultry health and performance, their impact under present-day environmental and economic pressures and the path forward for sustainable poultry nutrition.

Current challenges in poultry feeding and production

Feed resource limitations

Conventional feed ingredients like soybean meal and maize are subject to price volatility and regional shortages. Competition with human food and biofuel industries further reduces their availability. Climate change is reducing crop yields, affecting feed supply chains globally.

Antibiotic resistance and ban on antibiotic growth promoters (AGPs)

The European Union (EU) and many other regions have banned AGPs due to rising antimicrobial resistance (AMR). The need to maintain bird health and productivity without antibiotics requires alternative approaches.

Disease and environmental stress

Poultry are highly susceptible to climate-induced stressors such as heat stress. Diseases like coccidiosis, necrotic enteritis and avian influenza continue to pose threats to flock health and productivity.

Sustainability pressures

Environmental concerns linked to feed production, including deforestation, water use and greenhouse gas emissions require attention. Consumers increasingly demand traceable, eco-friendly and welfare-centric poultry products.

What are next-generation feeds and feed additives?

Next-generation poultry feeds are advanced formulations designed to maximize nutrient utilization, support gut health, enhance immunity and reduce environmental impact. They are customized using precision nutrition tools and fortified with functional feed additives.

Key components include:

Alternative feed ingredients (insects, algae, DDGS, etc.),

Functional feed additives (probiotics, prebiotics, phytogenics, enzymes),

Precision-formulated rations,

Digital and AI-based feed optimization tools,

Alternative and sustainable feed ingredients

Insect-based proteins

Black soldier fly larvae (BSFL), mealworms and crickets are rich in protein, fats and micronutrients. Studies show BSFL can replace up to 50% of soybean meal in broiler diets without compromising growth.

Algae and seaweeds

Microalgae such as Spirulina and Chlorella are high in protein and bioactive compounds. Seaweeds offer anti-microbial and prebiotic benefits while improving egg yolk pigmentation.

Distillers dried grains with solubles (DDGS)

A by-product of bioethanol production, DDGS are cost-effective, protein-rich and enhance feed sustainability.

Agricultural by-products

Rice bran, oilseed meals and cassava peels, when properly processed, offer viable alternatives.

Key feed additives in next-generation poultry nutrition

Probiotics

Live beneficial microbes (e.g., Lactobacillus, Bacillus) that colonize the gut. Improve gut health, competitive exclusion of pathogens and immune modulation.

Prebiotics

Non-digestible fibres that stimulate growth of beneficial gut bacteria. Examples: mannan-oligosaccharides (MOS), fructo-oligosaccharides (FOS) and beta-glucans.

Phytogenic feed additives (PFAs)

Plant-derived compounds include herbs, spices, condensed tannins, saponins and essential oils (e.g., oregano, thyme, cinnamon). They possess antimicrobial, antioxidant, anthelmintic, anticoccidial and growth-promoting properties.

Enzymes

Dietary supplementation of exogenous enzymes as feed additives improve digestibility of complex feed components. Common enzymes include phytase, xylanase, protease and amylase, etc. They also reduce anti-nutritional factors and nutrient excretion, enhancing environmental sustainability.

Organic acids

The organic acids supplementation in the diet of poultry as feed additives can lower gut pH and inhibit pathogenic bacteria (e.g., *Salmonella* and *E. coli*). The commonly used organic acids as feed additives are formic, lactic, propionic and citric acid.

Mycotoxin binders

They protect birds from mycotoxins present in contaminated feed. Some of the important

mycotoxin binders commonly used in commercial poultry feeds are bentonites, zeolites and activated charcoal.

Immunomodulators

Include compounds like beta-glucans, nucleotides and specific peptides that enhance the immune system.

Precision poultry nutrition

Precision poultry nutrition is an advanced feeding approach that tailors nutrient delivery to the specific needs of birds based on their age, breed, health status, and production goals. Unlike traditional one-size-fits-all feeding, precision nutrition optimizes feed composition using real-time data, improving growth rates, feed conversion ratios, and overall bird health.

Technologies such as automated feeders, sensors, and AI-driven modelling allow for accurate monitoring of feed intake, weight gain, and environmental factors. This ensures the right balance of protein, energy, vitamins and minerals is provided at every stage of development.

Precision nutrition reduces feed waste, lowers production costs, and minimizes environmental impact by decreasing nutrient excretion. It also supports antibiotic-free and sustainable poultry production. As global demand for poultry meat and eggs grows, precision nutrition plays a crucial role in achieving efficiency, sustainability, and animal welfare in modern poultry farming.

Precision poultry nutrition involves individual nutrient profiling, life-stage specific formulations and real-time monitoring. Tools like near-infrared reflectance spectroscopy (NIRS), artificial intelligence (AI) and blockchain optimize feed composition, reduce waste and enhance traceability. Precision feeding reduces over- or under-supplementation, optimizing performance and minimizing cost.

The evolution of poultry nutrition has entered a new era with next-generation feeds and feed additives, driven by the need for efficiency, sustainability, and improved bird health. Central to this innovation are precision-formulated rations and the integration of digital tools and sustainable feed ingredients, reshaping modern poultry production systems.

Precision-formulated rations

Precision nutrition involves formulating poultry diets based on the exact nutrient requirements of birds at different growth stages, breeds, and production goals. Using real-time

data from automated feeders, sensors, and growth monitoring tools, nutritionists can fine-tune rations to ensure optimal protein, energy, vitamins, and mineral balance. This targeted approach enhances feed conversion ratios (FCR), reduces overfeeding, and minimizes nutrient wastage. It also lowers production costs and supports uniform growth across flocks. Phase feeding and split feeding are common precision strategies that align nutrient supply with physiological needs.

Digital tools for smart nutrition

Digital platforms and artificial intelligence (AI) are increasingly being used to support precision feeding. Software tools analyze data from feed mills, farms, and animal performance metrics to suggest diet adjustments in real-time. Mobile apps and cloud-based dashboards help farmers track feed intake, environmental conditions, and health indicators. These tools enable proactive nutrition management, early detection of performance issues, and better decision-making.

Sustainable feed ingredients

To reduce dependency on conventional feed ingredients like soybean meal and fishmeal, next-gen poultry diets are incorporating alternative, eco-friendly inputs. These include insect meal (e.g., black soldier fly larvae), single-cell proteins (from algae, yeast, and bacteria), agro-industrial by-products, and locally sourced grains and oilseeds. These ingredients not only lower the environmental footprint of feed production but also promote circular economy practices by utilizing waste streams.

Functional feed additives

Advanced additives such as enzymes, probiotics, phytogenics, organic acids, and antioxidants are integral to these feeds. They improve nutrient utilization, enhance gut health, and reduce the need for antibiotics, aligning with consumer demand for natural, residue-free poultry products. Next-generation feeds combining precision-formulated rations, digital technologies and sustainable ingredients are paving the way for more productive, eco-friendly and profitable poultry farming.

Benefits of next-generation feeds and feed additives

Next-generation feeds and feed additives are transforming poultry nutrition by enhancing productivity, improving health and promoting sustainability. These innovations are designed to meet the growing global demand for poultry products while addressing concerns related to feed efficiency, antibiotic use and environmental impact.

Enhanced growth and feed efficiency:

Formulated with highly digestible ingredients, next-generation feeds ensure better nutrient absorption, leading to faster growth and improved feed conversion ratios (FCR). Precision-balanced diets tailored to the bird's specific growth stage and genetic potential help optimize weight gain and reduce feed waste.

Gut health and immunity

Advanced feed additives such as probiotics, prebiotics, organic acids, and enzymes play a critical role in supporting gut health. They enhance digestion, maintain a healthy gut microbiota, and strengthen the immune system, reducing reliance on antibiotics and mitigating disease outbreaks.

Natural growth promotion

Phytogenic additives—derived from herbs, spices, and plant extracts—serve as natural growth promoters. They improve appetite, enhance digestive enzyme activity, and offer antimicrobial and antioxidant benefits, contributing to overall bird performance and health.

Reduced environmental impact

Enzyme-based additives such as phytase and protease improve nutrient utilization and reduce nutrient excretion, particularly nitrogen and phosphorus, into the environment. This leads to lower emissions and improved manure quality, supporting eco-friendly poultry production.

Meat and egg quality improvement

Certain additives, including omega-3 fatty acids, selenium, and vitamin E, enhance the nutritional profile, flavour and shelf life of poultry meat and eggs. This not only meets consumer demand for healthier products but also adds value to poultry outputs.

Improved growth and feed conversion

Probiotics and enzymes enhance nutrient absorption and metabolism. Birds reach market weight faster with better feed conversion ratio (FCR).

Enhanced disease resistance

Functional additives strengthen immunity and reduce disease outbreaks, minimizing the need for antibiotics.

Heat stress mitigation

Supplements like chromium, vitamin C and betaine improve thermotolerance.

Improved product quality

Enriched feeds improve egg shell strength, yolk color, meat texture, and nutritional profile (e.g., omega-3 enrichment).

Environmental sustainability

Enzymes and precision feeding reduce nutrient excretion, decreasing nitrogen and phosphorus pollution.

Cost-effectiveness / Economic efficiency

Lower feed costs via alternative ingredients. Reduced mortality and better performance improve profit margins. While initial investment in next-gen feeds and additives may be higher, the long-term benefits in terms of improved efficiency, reduced mortality and better market quality make them economically viable.

Overall, next-generation feeds and feed additives offer a holistic approach to modern poultry production, combining performance, health, sustainability and profitability.

Case studies

India: Herbal additives in layer diets

Indian poultry farms using turmeric and neem-based feed additives recorded improved egg production and yolk pigmentation, with reduced mortality.

Netherlands: Algae-based feed trials

Algae-enriched broiler diets showed a 10% increase in growth rate and significant improvements in gut health and immunity.

Kenya: Insect-based poultry feed

BSFL meal replaced 25% of soybean in smallholder broiler diets, resulting in a 15% cost saving and no adverse effects on growth.

Challenges and barriers to adoption

Cost of certain feed additives, especially when used at scale,

Lack of farmer awareness and technical know-how,

Inconsistent regulation of feed additives across countries,

Quality control issues in the production of novel ingredients like insects or algae,

Resistance to change in traditional farming communities,

Strategies for promoting adoption

Research and development

Focused R and D on local feed ingredients and cost-effective additives,

Nutrigenomics and gut microbiome studies to personalize poultry nutrition,

Policy and regulation

Establish clear standards and safety protocols for next-generation additives,

Ban on AGPs to be complemented by support for alternatives,

Capacity building

Training farmers, nutritionists and feed millers on modern feed strategies.

Public-private partnerships (PPP)

University scientist/ academia, feed companies and governments need collaboration among each other to scale innovation.

Incentives and support

Financial incentives for using sustainable feed options. Encourage local production of alternative proteins (insect meal) by local farmers for feeding of poultry.

Future directions

Applications of AI and big data to enable real-time diet optimization,

Gut health modulation as the central axis of disease control,

Fermented feed technologies to enhance digestibility and gut function,

Carbon footprint labelling of feed to support climate-smart poultry products,

Expansion of lab-grown feed ingredients and microbial proteins.

Conclusion

Next-generation feeds and feed additives represent a revolutionary leap in poultry nutrition. By moving beyond conventional approaches, these innovations offer solutions to many of the urgent problems facing the industry—ranging from antibiotic resistance and disease outbreaks to feed cost inflation and climate stress. They allow producers to enhance bird health, productivity, and profitability while simultaneously addressing consumer demand for sustainability and food safety. Adoption of these technologies must be supported by strong policy frameworks, continued research, and widespread knowledge dissemination. In an era where poultry production must do more with less, next-generation nutrition is not just an opportunity. It is an essential pathway to a resilient, ethical and efficient poultry sector.

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HORTICULTURE SCENARIO IN TAMIL NADU: STRATEGIES TOWARDS ATTAINING SUSTAINABLE GOALS

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Introduction

Horticulture sector includes a diversity of crops such as fruits, vegetables, spices and condiments, plantation crops, flowers and medicinal and aromatic plants. Major fruit crops are Banana, Mango, Citrus, Grapes, Guava, Sapota, Papaya and Pine apple. These are grown in 2,93,146 ha mainly in districts like Krishnagiri, Dindigul, Thirunelveli, Vellore, Theni, Erode, Trichy, Thiruvallur, Dharmapuri and Madurai. Major Vegetable crops grown are Tapioca, Onion, Tomato, Potato, Brinjal, Bhendi, Drumstick, beans and Carrot in an area of 2,26,502 ha mainly in districts like Namakkal, Salem, Dharmapuri, Trichy, Tiruppur, Dindigul, Erode, Villupuram, Krishnagiri, Perambalur, Nilgiris and Theni Districts. Important Spices and Condiments grown are Chillies, Turmeric, Tamarind, Coriander, Pepper, Cardamom and Cloves in an area of 1,45,559 ha in districts like Ramnad, Thoothukudi, Erode, Salem, Virudhunagar, Dindigul, Dharmapuri and Sivagangai Districts.

Tea, Coffee, Rubber and Cashew are the important Plantation Crops grown in an area of 2, 32,988 ha in Districts like Nilgiris, Ariyalur, Cuddalore, Kanyakumari, Dindigul, Coimbatore, Pudukottai and Salem. In addition to the traditional flowers like Jasmine, Crossandra, Tuberose, and Chrysanthemum, cut flowers like Rose, Carnations and Gerbera are also being produced in the State. The cut-flower industry is growing day by day due to high export prospects. Flowers are grown in an area of 25309 ha in districts like Dindigul, Dharmapuri, Krishnagiri, Salem, Madurai, Tirunelveli, Thiruvallur, Vellore and Thiruvannamalai. Medicinal and Aromatic crops like Gloriosa, Senna, Coleus, Lemon-grass and Periwinkle are grown in an area of 11,230 ha in

districts like Virudhunagar, Dindigul, Thiruvallur, Ariyalur, Madurai, Thiruvarur, Dharmapuri, Salem, Nagapattinam and Trichy.

Tamil Nadu witnessed tremendous shift in area from food grain to horticulture crops over the last five years. The production of horticulture crops has outpaced the production of food grain since then. Significant progress has been made in area expansion resulting in higher production.

Hybrid vegetable cultivation has offered immense scope in the increase in vegetable production in the last few years. The hybrid vegetable protray seedling production has led to a phenomenal increase in the area and production under vegetable cultivation. Other developmental activities such as area expansion, protected cultivation structures, Integrated Pest, Disease and Nutrient Management and micro Irrigation for increasing the productivity has paved way for increasing the production. Due to health safety concerns, the importance of organic vegetable production is also growing in the State. There is a sure and high end market for organically grown vegetables and many of the corporate companies have also entered into vegetable production by the introduction of IT platforms in agriculture.

There has been increase in the certified seed production of vegetable crops for expansion of area and promotion of kitchen garden in households. Presently horticulture has established its credibility in improving income through increased productivity, generating employment and in enhancing exports. Resultantly, horticulture has moved from rural confines to commercial venture.

Good potentialities exist for cultivation of flowering plants. Increasing trends in area and production of flowers has been observed over the last few years. In addition to the beautification of the local landscape, great scope exists for export of flowers; and floriculture is important for bee-keeping industry which provides an alternate source of income to the Indian farmers.

Infrastructure

Prices of horticultural commodities fluctuate in accordance with their supply and demand situation which, in turn is characterized by seasonality of production and marketing. Horticulture commodities are produced seasonally and are perishable. On account of these characteristics, such commodities register fluctuation of prices which ultimately affect the returns to the growers. The seasonality and perishable nature of horticulture crops demands coordination between supply and demand wherein storage plays an important role in the marketing.

State intervention in input prices

The bulk of several key material inputs used by agriculture *viz*., surface irrigation, energy for groundwater irrigation, agrochemicals and rural credit is produced and supplied through public sector organizations. The pricing of all these inputs is decided and enforced by government to ensure that they are affordable by the farming community. This has been and remains the overriding objective of policy. The political argument is that these measures have been and continue to be justified for helping the poverty-stricken farming community. The economic argument is that cheap inputs are necessary to induce adoption and spread of yield augmenting technology and inputs on a scale and at a pace needed to achieve and sustain rapid growth of agricultural output. Whatever may have been the validity of these arguments in the initial years of planning; there is little justification for deliberately persisting with the policy. The rapid growth in the supply of yield augmenting inputs has been matched, in fact more than matched, by demand. Costs of production and distribution show spiraling growth. And yet, nominal input prices for all key material inputs have been kept unchanged and even reduced in many cases.

Production and distribution of inputs

Governments and public enterprises have played an important direct role in the production, distribution and pricing of key material and financial inputs as well as in processing and marketing of produce and indirectly through regulation of private players in these activities. The management of these activities and their performance are again an area of serious concern. But decisions on these interventions and the manner in which they are implemented with scant regard for their impact on efficient, sustainable and equitable growth. For instance, inefficiency and rising costs of public sector production of seeds, fertilizers and energy are well known. Farmers have been insulated from this by supplying them at highly subsidized prices.

Precision Horticulture

Precision horticulture, which can provide precise inputs like water, fertilizer, insecticides at the right time to crops, can help bring in the next green revolution. Drones are being used quite regularly in Japan and US for insecticide application to the crops. Use of drones for agriculture is proverbial "turning swords into ploughs!" Most of these robotic machines and drones are small in size and hence are very suitable and excellent match for small farm applications. Thus small farm size of India is a blessing in disguise for large scale application of precision agriculture.

Precision agriculture in US and other countries has shown tremendous increase in productivity, lowering of inputs and hence increased remuneration to the farmers. Besides it has helped improve the quality of land with no-till farming and less water usage. Similar things are possible in India with its use. However, the biggest criticism of mechanized agriculture is that farm machinery is very costly and no farmer, including big ones, can afford it. However, application of inputs at proper time requires timely availability of labour, water and fertilizers all of which are becoming scarcer and scarcer. Besides, majority of farms are rainfed and with the change of weather patterns, availability of rainwater is very unpredictable. Hence the non-availability of inputs and labour on time is the biggest stumbling block to increase productivity of farms and remuneration.

High tech Precision horticulture therefore can help in bringing next green revolution to India and can produce tremendous rural wealth in a sustainable and environmentally sound way. Precision horticulture is a step in the right direction.

Cultivation of minor fruits

Minor fruits like litchi, jamun, pear, peach *etc* are presently grown in a limited extent only and are not usually cropped in organized plantations. They are in general hardy and grow well even in fragile soil and climate and having potential for intensive exploitation. Attacks by deadly pests and diseases are relatively less in many of these crops. Similarly introduction of arid zone fruit crops in dry lands offers greater scope since they are adapted to the local climate, are highly nutritious and contribute to poverty elevation and household food security of rural people and play a significant role in herbal medicine. Though a wide range of diversity of underutilized fruit crops exists in diverse agro-ecological zones of Tamil Nadu, there are no organized orchards and no recognized cultivars for almost all of these minor or underutilized crops and some of those are being eroded from the plant wealth list.

High Density Planting System

The benefits under UHDP include two to three-fold increases in productivity, optimal use of vertical and horizontal space, increased water-use and fertilizer use efficiency, possibility of using the space between plants for intercropping during early years of planting besides making orchard crops profitable as other cash crops. UHDP combined with micro irrigation, fertigation, canopy management and pruning can play an important role in achieving quick, high, stable and sustainable yields in fruit crops.

The modern idea of vertical farming uses techniques where natural sunlight may be augmented with artificial structure. The idea of vertical farming has existed at least since the "Hanging Garden of Babylon". The concept of a Vertical Farm (VF) has existed theoretically since the early 1950s. The spectrum of various components in the urban and peri-urban ecosystem is also changing continuously. Intensifying indoor urban farming through the establishment of vertical farms (or high-rise farms) in urban centres is the likely solution to the swelling human population. Vertical farming or high-rise farming or sky farming is a proposed indoor, urban farming technology involving large-scale agricultural production in multi-story buildings. It is an intensive farming strategy which mainly employs advanced techniques such as hydroponics and Aeroponics to produce crops like fruits, vegetables and edible mushrooms continuously. It also includes the raising of livestock and fishes indoo

Vertical farming

A good example of a frontier horticultural production system is vertical farming. With exponential increase in population and fast shrinking agricultural land scientists and policy makers are giving serious thoughts to vertical farming that can effectively use the urban spaces for growing horticultural crops.

Doubling Farmers' Income

Doubling the production and tripling the income of farmers is the prime policy of Tamil Nadu. This challenge has been taken up by implementing several developmental schemes and also through propagation of relevant technologies to step up the production. The Government implemented the scheme on doubling of farmers' income in the year 2022. It focused on seven sources of income growth *viz*, improvement in crop and livestock productivity; resource use efficiency or savings in the cost of production; increase in the cropping intensity; diversification towards high value crops; improvement in real prices received by farmers; and shift from farm to non-farm occupations. Due to the efforts made as part of schemes/ programmes of the Department of Agriculture and Farmers Welfare with the strategy of doubling farmers income, there has been an appreciable improvement in efficiency bringing about a positive impact in the agriculture sector.

Farming Corporatization

An idea of corporate farming is that which allows a corporate own a farming of a village.

The corporate would provide all the technologies, infrastructures (like cold storages, food processing units etc). Finally the corporate would take back all the crops.

Conclusion

The critical issues that plague Indian agriculture at present are the knowledge deficit and infrastructure deficit, especially in the rural areas. Problems related to irrigation infrastructure, market infrastructure and transport infrastructure add significant cost to farmers' operations. Another issue is lack of delivery mechanisms. There are a number of schemes aimed to bring development in agriculture. We do not have effective delivery mechanisms that can translate into effective facilitation in terms of increasing productivity or decreasing cost or increasing price realization at the ground level. Moreover, inadequate government support exacerbates these issues. Thus, corporate farming could be a solution to Indian agrarian sector, but it needs a deep thinking and innovating better policies so that neither the corporates nor the farmers be at loss.

Eminent experts should do research in this aspect and governments must take a proactive action. Indian agrarian sector in fact requires very innovative ideas for uplifting of this sector. Also, without mechanization, farming is hard and back-breaking work. This has resulted in most farmers' children quitting farming and going for other vocations. Farmers get more money in selling their land to builders, malls and factories. This has put more pressure on farmland, thereby requiring technologies to increase the productivity so that shrinking farmland can feed billion plus people of India in the future. India, though one of the biggest producers of agricultural products, has very low farm productivity, with the average only 33 percent of the best farms world over. This needs to be increased so that farmers can get more remuneration from the same piece of land with less labour.

Horticulture sector is recognized to have the potential to raise the farm income, provide livelihood security and earn foreign exchange. However, focused policy interventions are needed to realize the potential of the sector.

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TAMARIND CULTIVATION IN INDIA

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Introduction

Tamil Nadu, Karnataka, Kerala, Andhra Pradesh, Telangana, Maharashtra, Madhya Pradesh, Uttar Pradesh, and Odisha are the leading tamarind-producing states in India, covering an area of approximately 39,639 hectares. The total production is around 1,48,958 tonnes, with an average productivity of 3.7 tonnes per hectare (1).



Tamarind plant

Nutritional Composition

Tamarind pulp provides 239 kilocalories of energy, along with 62.5 grams of carbohydrates, of which 57.4 grams are sugars. It contains 2.8 grams of protein and 0.6 grams of fat, including 0.2 grams of saturated fat. Dietary fibre content is 5.1 grams. In terms of vitamins, it offers 81 micrograms of Vitamin A, 3.5 milligrams of Vitamin C, 0.1 milligrams each of

Thiamine (Vitamin B1) and Riboflavin (Vitamin B2), and 1.9 milligrams of Niacin (Vitamin B3). It also includes 14 micrograms of Folate (Vitamin B9). Among minerals, tamarind pulp contains 74 milligrams of calcium, 2.8 milligrams of iron, 92 milligrams of magnesium, 113 milligrams of phosphorus, 628 milligrams of potassium, and 28 milligrams of sodium.[2].

Crop Characteristics: Tamarind is a tropical crop. It can be cultivated even in barren lands with low rainfall in upland areas.

Uses: It is a multi-purpose tree; the fruit, seeds, tender leaves, bark, and roots are useful to humans in various ways. Bioactive Compounds of Tartaric acid, Polyphenols, Pectin, Tannins present in tamarind provide tremendous health benefits as polyphenols, that help neutralize harmful free radicals in the body, potentially reducing the risk of chronic diseases. The dietary fiber and pectin promote healthy digestion, alleviate constipation and support gastrointestinal health. Tannins, have been studied for their anti-inflammatory properties, which may aid in managing inflammatory conditions. Tamarind may help regulate blood sugar levels due to its low. glycemic index and ability to inhibit enzymes involved in carbohydrate digestion. Potassium in tamarind supports heart health by regulating blood pressure and reducing the risk of cardiovascular diseases. Tamarind trees help prevent soil erosion and can serve as windbreaks Additionally; the leaves and bark of the tamarind tree are used for medicinal purposes and in making organic fertilizers.

Tamarind seeds contain a polysaccharide called xyloglucan, which is used in textile printing, paper making and in the production of adhesives and explosives. Seed powder (after removing the shell) is used as cattle feed, in coffee powder, dye manufacturing, and in the textile industry.



Tamarind leaves

Soil: Though tamarind can grow in all types of soils, deep loamy or red gravelly soils are suitable. It can tolerate saline-alkaline soils up to 40% ESP. The ideal pH range is 6.5 to 8.0.

Climate: It grows well in hot and dry climates and needs 750–1000 mm rainfall annually. However, it also grows well in upland areas with 500–760 mm rainfall. It thrives at temperatures between 33.5–37.1°C. Mature trees can tolerate temperatures as low as 17°C but are susceptible to frost and waterlogging.

Varieties: Notable varieties include P.K.M-1, Pratishthan, Urigam, DTS-1, DTS-2, Yogeshwari, Tamarind-263, Goma Prateek, Thettu Amalika, Anatha Rudhira, Sweet tamarind, red pulp and seedless types

Seedling Preparation: Seeds are collected in January-February and can be stored for up to a year. There are about 900 to 1600 seeds per kilogram. Seeds should be soaked in cold water for 24 hours and planted in 6×0 polybags. They germinate within a week. If planted in February, seedlings will be ready by July. Seedlings take 10–14 years to bear fruit, while grafted plants take 4–7 years. Propagation is done through softwood grafting and budding.

Planting Time: Best time is June–July. In irrigated areas, planting can be extended until September.

Planting Density: 40 to 60 trees per acre can be planted with spacing of 10m×10m or 8m×8m. Along roads, trees can be planted 10–12 meters apart. One-year-old seedlings should be planted at the onset of the monsoon.

Irrigation: In irrigated areas, water should be given every three weeks during summer. Young plants need irrigation during the first 2–3 years.

Fertilizer Management: Though no standard recommendation exists, based on soil and climate for 1-year-old trees apply 10 kg FYM + 100g nitrogen + 50g phosphorus + 100g potash. Increase dosage annually. For 10-year-old trees 50 kg FYM + 1 kg nitrogen + 500g phosphorus + 500g potash. In irrigated conditions, apply an extra 500g nitrogen in September–October. Foliar sprays like Cycocel (1500 ppm), Ethrel (500 ppm), Triacontanol (20 ml/tree), BBA (150 ppm), Planofix (100 ppm), and a micronutrient mix (Zinc sulphate 0.5% + Boric acid 0.3% + Ferrous sulphate 0.5% + Urea 1.5%) improve flowering, fruit setting, yield, and quality.

Soil Preparation: Deep ploughing before planting and annually during the monsoon helps in weed control and improves water retention.

Pruning: During the first year, pruning is done to develop a proper structure (modified leader system). Remove water shoots, dry twigs, and diseased branches.

Intercropping: Agricultural crops can be grown profitably for the first 4–5 years. Afterward, fodder crops can be cultivated.

Flowering and Fruiting: Flowering begins in April and continues till July. Fruit set occurs due to cross-pollination. It takes 8–10 months from flowering to fruit maturity.

Though, flowering is profuse in tamarind, the fruit set under natural conditions is low, ranging from 3-5%, which can be increased to about 50-55% under artificial cross pollination. Pollen limitation, floral abnormalities are some of the reasons for low fruit set under open pollinated condition. The higher fruit set in controlled cross-pollinated flowers as compared to selfing indicated the existence of partial self-incompatibility in tamarind, The fruit set was found to be increased when the number of pollinators (honey bees) visiting the tree was high (3).

Plant Protection

Diseases: Leaf spot, sooty mold, and powdery mildew are common diseases.

Use wettable Sulphur 2g or Captan 2g or Carbendazim 1g per liter of water for spraying.

Insects: Pod borers: Spray Carbaryl 3g/liter.

Leaf-eating caterpillars: Spray Quinolphos 2 ml or Chlorpyrifos 2.5 ml per liter.

Scale insects, mealy bugs, whiteflies, and lac insects: Spray Carbosulfan 0.1% or Profenophos 2 ml/liter.

Thrips and aphids: Spray fenthion 1 ml/liter.



Tamarind fruit

Yield:

On an average 7–8-year-old trees yield 30–40 kg/tree. By 15 years, trees can yield 80–90 kg/tree. Trees over 20 years can yield over 200 kg. Trees can bear fruit every alternate year for up to 80 years.

Post-Harvest and Storage:

After harvesting, tamarind pods should be sun-dried. The dried outer shell is removed, and the pulp is stored. Under normal conditions, pulp can be stored for one year. In cold storage (4–6°C, 75–80% humidity), it lasts longer without quality loss.



Tamarind



Tamarind Seed



Seed powder

Marketing:

Tamarind seeds are separated before marketing. The 'Flower' variety fetches a higher price. Tamarind is also sold in salted balls. Tamarind is exported from India to Europe and the U.S.

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TOMATO STRAW COMPOSTING

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Introduction

Tomatoes, a globally popular and economically significant commercial vegetable crop, play a vital role in food processing, fresh consumption, and the production of various agricultural products. While their high yield has brought considerable economic benefits, it has also led to the generation of substantial amounts of tomato straw waste. As a common byproduct in agricultural production, if not properly managed, these straws not only increase the burden of agricultural waste management, but also pose a potential risk to the environment. Therefore, the development of effective resource utilization technologies for tomato straw waste is crucial not only for mitigating environmental pollution, but also for enhancing resource efficiency, which plays a key role in the long-term sustainability of agriculture development.

In recent years, the resourceful treatment of agricultural waste has garnered increasing attention, with composting and vermicomposting technologies emerging as widely applied methods in the field. Composting is a well-established technique for treating agricultural waste, harnessing the power of microorganisms to transform such waste into organic fertilizers or soil amendments. Among the leading techniques for managing organic waste, this technology significantly reduces waste volume, lowers electrical conductivity, and facilitates the degradation of harmful substances, effectively preventing environmental pollution. Furthermore, composting can be implemented on an industrial scale, capable of processing large quantities of solid organic waste with high production efficiency. However, the quality of compost products can be inconsistent, not always achieving desirable outcomes in terms of nutrient content, soil amendment effects, and economic costs.

Tomato straw, the plant residue left over from tomato harvests, is a valuable resource that can be composted and used as a soil amendment. Composting tomato straw offers numerous benefits, including improving soil structure, providing essential nutrients, and reducing waste.

Resource Utilization:

Tomato straw, often a byproduct of tomato cultivation, can be repurposed into a valuable resource through composting.

Soil Improvement:

Composted tomato straw can improve soil structure, aeration, and water retention, making it more suitable for plant growth.

Nutrient Source:

The compost provides essential nutrients for plants, including nitrogen, phosphorus, and potassium, reducing the need for synthetic fertilizers.

Potential Benefits:

Studies have shown that using tomato straw compost can lead to increased tomato yields, especially in situations where salty water irrigation is used.

Versatile Application:

Tomato straw compost can be used in various contexts, including field cultivation, container gardening, and even as a component of mulches.

Sustainable Practice:

Utilizing tomato straw compost promotes a more sustainable agricultural approach by reducing waste and closing nutrient cycles



Materials:

Tomato straw:

This is the primary material being composted. It should be dried and crushed into smaller pieces (1-4 cm) for faster decomposition.

"Greens" (Nitrogen-rich materials):

Weeds (to add more nutrients).

Kitchen scraps (fruit, vegetable, and coffee grounds).

Manure (cattle, horse, etc.).

"Browns" (Carbon-rich materials):

Shredded paper, cardboard, or brown bags.

Wood chips or sawdust (for aeration).

Dried leaves.

Straw (or other dried plant matter).

Microbial consortia (optional):

Consortia of *Trichoderma viride* and *Pleurotus sajor-caju* (for faster decomposition).

Urea (optional): Urea (to accelerate the composting process).

Methodology:

1. Prepare the material:

Cut tomato straw into smaller pieces (1-4 cm) for better decomposition.

2. Layer the materials:

Alternate layers of "greens" and "browns" in a compost pile, ensuring a balance of nitrogen carbon.

3. Maintain moisture:

Keep the pile moist (like a wrung-out sponge) by sprinkling water as needed.

4. Ensure aeration:

Turn the pile periodically (every 2-3 weeks) to allow oxygen to reach the microbes.

5. Add microbial consortia and urea (optional):

If using, sprinkle the consortia and urea over the layers to boost decomposition.

6. Monitor and adjust:

Observe the temperature and moisture levels, and adjust the mixture as needed.

7. Compost time:

The compost is typically ready in 30-60 days, depending on the materials and conditions.

8. Use the compost:

Once mature, the compost can be used as mulch around tomato plants or incorporated into the soil for planting.

Tips:

- **Avoid:** Meat scraps, dairy products, and diseased plants.
- **Consider:** Adding a layer of soil on top of the pile.
- **Turn the pile:** Thoroughly turn the pile on the 21st day.
- **Mulching:** Use the compost as a mulch to retain moisture, suppress weeds, and add nutrients to the soil

What is Tomato Straw Compost?

Tomato straw compost is the product of a composting process that breaks down the stalks, vines, and leaves of tomato plants into a nutrient-rich, organic soil amendment.

Benefits of Tomato straw compost

Improves Soil Structure:

Composting tomato straw helps to improve soil aeration, water retention, and overall soil structure, creating a healthier environment for plant roots.

Provides Nutrients:

The composted straw releases essential nutrients back into the soil, supporting healthy plant growth and fruit production.

Reduces Waste:

Composting tomato straw helps to divert agricultural waste from landfills and convert it into a valuable resource, reducing environmental impact.

Suppresses Weeds:

Straw mulch, a byproduct of composting, can also help to suppress weed growth, saving time and effort on weeding.

Enhances Water Holding Capacity:

And Tomato straw compost can improve soil's ability to retain water, which is crucial in drier climates or during periods of drought.

Alternate source:

Tomato straw can be effectively composted with other organic materials like manure, yard waste, or even certain types of food scraps Tomato straw can be composted using a mix of "greens" (nitrogen-rich materials) and "browns" (carbon-rich materials) to create a nutrient-rich soil amendment. The process involves layering these materials, maintaining moisture and aeration, and turning the pile periodically.

The composted straw can then be used as mulch or incorporated into the soil for tomato plants.

Conclusion

- Tomato straw compost is a valuable resource for improving soil health and enhancing plant growth, especially when used in conjunction with other materials and composting techniques.
- By optimizing composting processes and incorporating tomato straw into balanced fertilization strategies, farmers can effectively utilize this waste product to improve soil fertility and reduce reliance on synthetic fertilizers.

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USES OF DISTILLERY SPENT WASH IN AGRICULTURE

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Abstract

Distillery spent wash, a major by-product of the distillation industry, is rich in organic matter, plant nutrients, and beneficial microorganisms, making it a potential resource for agricultural applications. Its effective utilization in agriculture has gained attention due to its ability to improve soil fertility, enhance crop productivity, and promote sustainable waste management. Spent wash is known to supply essential macro and micronutrients such as nitrogen, phosphorus, potassium, calcium, magnesium, and sulphur, along with trace elements. When applied in controlled quantities, it improves soil physicochemical properties, increases microbial activity, and supports organic matter build-up. Furthermore, it can serve as a substitute for chemical fertilizers and irrigation water, particularly in nutrient-depleted and saline-alkaline soils. However, its high organic load, color, and biological oxygen demand (BOD) necessitate proper treatment and dilution before agricultural use to avoid adverse environmental impacts. This review highlights the composition, application methods, benefits, and precautions associated with the use of distillery spent wash in agriculture, emphasizing its role in promoting eco-friendly and sustainable farming practices.

1. Introduction

The sugar industry ranks as the second largest agro-based industry in India, playing a key role in the country's economic growth. India hosts around 579 sugar mills and 350 distilleries. These mills process approximately 145 million tonnes of sugarcane annually to produce 14.5 million tonnes of sugar. Along with sugar, these industries also generate significant by-products

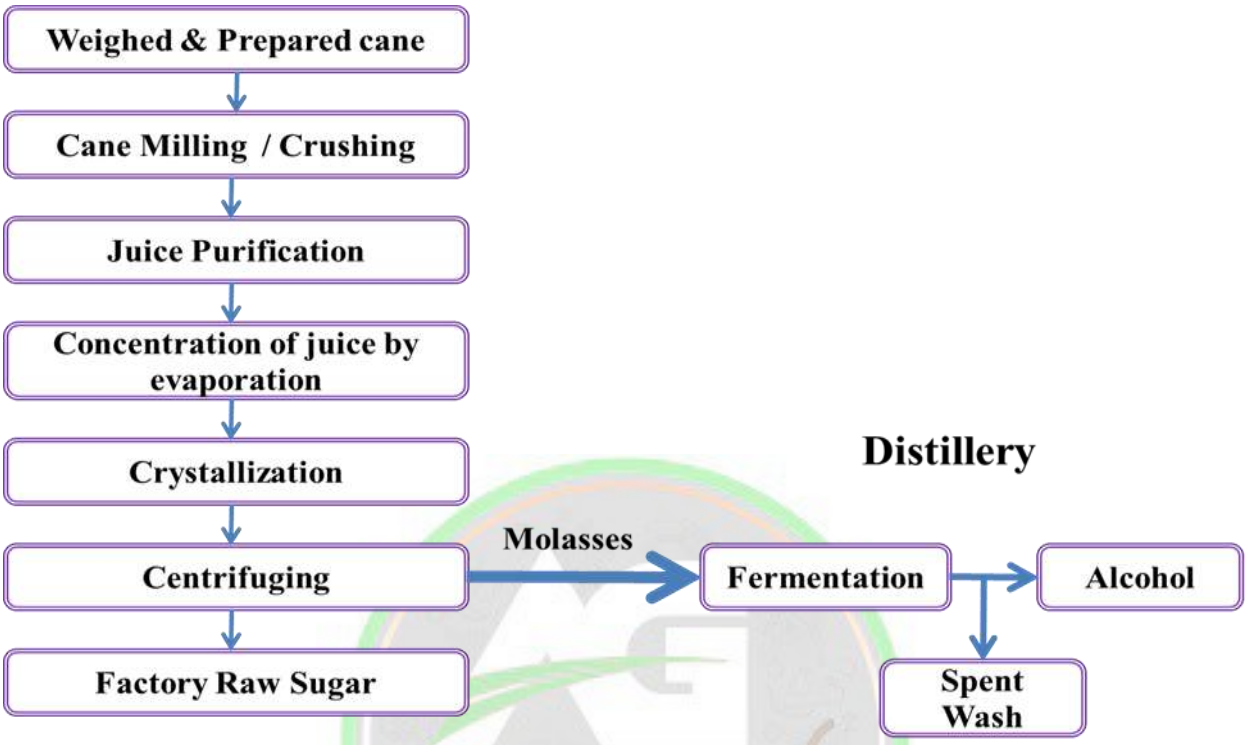
around 7 million tonnes of pressmud and 7.5 million tonnes of molasses each year. Among these, bagasse and molasses hold considerable economic value. Bagasse is widely used in producing paper, generating electricity, and as a fuel for boilers, while molasses serves as a low-cost raw material for alcohol production in distilleries through fermentation. Producing one litre of alcohol typically requires 3 to 10 kilograms of molasses.

According to the Central Pollution Control Board (CPCB), India has approximately 350 distilleries with a total alcohol production capacity of about 3800 million litres. These distilleries generate around 45 billion litres of wastewater annually. The alcohol industry, being a major agro-based sector, primarily uses molasses to produce rectified spirit and ethanol. However, this process also generates significant wastewater, especially from the fermented sludge, which is a major pollutant. Generally, for every litre of alcohol produced, distilleries discharge between 8 and 15 litres of wastewater, which is highly polluted with a biological oxygen demand (BOD) ranging from 45,000 to 60,000 mg/L and a chemical oxygen demand (COD) between 80,000 and 160,000 mg/L, along with a dark colour (Uppal, 2004). This effluent is known by various names globally, including stillage, vinasse, slop, dunder, and still residue. India's large network of distilleries, while effectively utilizing molasses, also ranks among the most polluting agro-industries due to the vast volumes of distillery spent wash (DSW) they produce. DSW is characterized by its dark colour, acidic nature, and high levels of BOD and COD, containing various biodegradable organic and inorganic materials. Due to its high pollutant load, it cannot be directly discharged into water bodies.

However, applying spent wash to agricultural lands provides a dual benefit it helps manage water pollution while also offering agricultural utility. To mitigate the high BOD, the biomethanation process is often employed, wherein the spent wash undergoes anaerobic digestion to reduce BOD levels by about 85%, resulting in what is known as Post-Methanated Distillery Spent Wash (PMDSW) (Rajkishore, 2008). Waste management remains a critical environmental challenge globally, with various industries producing wastewater that contains pollutants difficult and expensive to treat. Since wastewater characteristics vary across industries, there has been growing interest in utilizing industrial waste as a soil amendment. Distillery wastewater, when adequately diluted, can be used for irrigating crops without harming soil health, seed germination, or crop yields.

2. Spent wash Production

2.1. Sugar manufacturing process



Composition of distillery spent wash

Table 1. Composition of DSW from different distillery industries

Parameters	M/s. Bhavani Distilleries and chemical limited, Vellore, Tamil Nadu, India	Salem Co-operative Sugar Mills Ltd, Mohanur, Namakkal District, Tamil Nadu, India.	EID PARRY (I) LTD., Distillery, Nellikuppam, Tamil Nadu, India
Colour	Dark brown	Dark brown	Dark brown
Odour	Unpleasant	Unpleasant	-
Total dissolved solid (mg l^{-1})	42300	50000	-
Total suspended solids (mg l^{-1})	6100	3300	-
Total solids (mg l^{-1})	48400	53300	85000

pH	7.57	7.1	7.8
Electrical conductivity (dS m^{-1})	33.45	38	28.5
Total dissolved salts (mg l^{-1})	-	-	-
Setteable solids (mg l^{-1})	-	-	-
Organic carbon (mg l^{-1})	25200	24000	-
Chemical oxygen demand (COD) (mg l^{-1})	42800	35000	48000
Biological oxygen demand (BOD) (mg l^{-1})	11400	12800	4500
Carbonate (mg l^{-1})	-	-	-
Bicarbonate (mg l^{-1})	-	195	-
Total phosphorus (mg l^{-1})	-	-	-
Total Potassium (mg l^{-1})	-	-	-
Calcium (mg l^{-1})	2120	4600	2300
Magnesium (mg l^{-1})	1680	1752	2150
Sulphate (mg l^{-1})	-	947	4500
Sodium (mg l^{-1})	480	357	450
Chlorides (mg l^{-1})	-	13471	7500
Iron (mg l^{-1})	-	78	65
Manganese (mg l^{-1})	-	5.3	5.5
Zinc (mg l^{-1})	-	7.20	10
Copper (mg l^{-1})	-	5.5	4.2
Cadmium (mg l^{-1})	-	-	-
Lead (mg l^{-1})	-	-	-
Chromium (mg l^{-1})	-		-
Nickel (mg l^{-1})	-	-	-
Ammonical Nitrogen (mg l^{-1})	-		-
Nitrogen (mg l^{-1})	1700	420	1350
Phosphorus (mg l^{-1})	248	40	550
Potassium (mg l^{-1})	10680	9097	9500

Bacteria (x10⁶ CFU mL⁻¹)	21	12	-
Fungi (x10⁴ CFU mL⁻¹)	11	19	-
Actinomycetes (x10² CFU mL⁻¹)	3	Nil	-
	Selvamurugan *et al.* (2011)	Kalaiselvi and Mahimairaja (2009)	Anandakrishnan *et al.* (2008)

3. Effect of DSW on soil properties

3.1. Effect of DSW on physical properties of soil

Soil permeability and porosity are crucial factors to consider when planning the disposal of liquid waste onto agricultural lands. When large amounts of organic carbon compounds from distillery waste are applied to soils, they can lead to high oxygen demand caused by microbial activity under anaerobic conditions. This process may reduce the soil's infiltration rate and lower its hydraulic conductivity due to the buildup of solid residues. Neves et al. (1983) noted that the decline in hydraulic conductivity during distillery effluent irrigation was mainly due to solid accumulation on the soil surface. Similarly, Levy and Vander Watt (1990) found that an increase in exchangeable potassium levels in soil could also reduce its hydraulic conductivity. However, some studies have reported different outcomes. Joshi et al. (1996) found that applying distillery effluent improved the soil's saturated hydraulic conductivity and reduced bulk density compared to untreated soil. Soundararajan (2003) also observed a reduction in soil bulk density, while the particle density remained unchanged following the application of spent wash. Furthermore, research by Chandra et al. (2005) indicated that using distillery spent wash enhanced the soil's hydraulic conductivity. Likewise, Subash Chandra Bose et al. (2002) reported that applying increasing levels of distillery effluent reduced the bulk density and improved the water holding capacity of sandy soils.

3.2. Effect of DSW on chemical properties of soil

Application of spent wash has been found to significantly lower soil pH. Higher application rates of spent wash tend to cause a more noticeable decline in soil pH, and this effect becomes even more evident when combined with organic amendments. This reduction in pH is mainly due to the acidic nature of spent wash and the production of organic acids during the

decomposition process. Additionally, soil electrical conductivity (EC) increases considerably because of the accumulation of salts from spent wash. The calcium (Ca) present in spent wash can also displace sodium (Na^+) from soil exchange sites. Due to its complex composition, spent wash causes notable changes in soil chemical properties. Singh (1969) reported a slight decrease in soil pH after applying neutralized spent wash. However, other studies have documented an increase in soil pH and EC following the use of distillery effluent on agricultural fields. Mattiazo and Ada Gloria (1985) attributed this rise in pH to the microbial oxidation of organic matter in soils treated with distillery effluent. In some cases, spent wash application lowered both soil pH and Exchangeable Sodium Percentage (ESP) to safer levels. Nonetheless, an increase in soil pH after crop harvest has also been observed, possibly due to the leaching of soluble salts and further oxidation of organic matter. Subash Chandra Bose et al. (2002) found that soil pH significantly increased from its initial level following the application of distillery effluent, although the increase was not significant at lower application rates, such as 1.25 lakh litres per hectare. Moreover, the organic carbon content of post-harvest soils rose considerably with higher doses of distillery effluent. An increase of 0.11% in organic carbon was recorded with an application of 6.25 lakh litres per hectare, mainly due to the high organic matter content in the effluent.

3.3. Effect of DSW on soil biological properties

The distillery effluent being rich in nutrients and organic matter was found to improve the soil microbial populations. But observations recorded soon after the application of spentwash on soils showed an initial setback in the microbial populations and enzyme activities (Rajkishore, 2008). The spentwash @ 250 m^3 ha^{-1} stimulated the soil microorganisms and increased the dehydrogenase activity of the soil. Murugaragavan (2002) reported that the addition of raw spentwash at 125 m^3 ha^{-1} in dry land soils increased the activity of soil enzymes, viz., the phosphatase, dehydrogenase and urease. Further, the application of treated spentwash also increased the activities of these soil enzymes Nandakumar, 2009. Rajukkannu *et al.* (1996) revealed that application of distillery spent wash drastically reduced the number of bacteria, fungi and actinomycetes during the initial periods. The higher BOD of the DSW and the resultant depletion of oxygen in the soil would have drastically reduced the microbial population. However, the post-harvest soil samples had showed the built up of microbial population greater than the original level in the treated soil samples.

Therefore a minimum of 45 - 60 days should be given between the undiluted spent wash application and planting

4. Effect of DSW on crop growth and yield

Distillery spent wash effectively improve the growth and yield parameters of agricultural crops (Table 2)

Table 2. Effect of DSW on different crops

Crop	Response	Reference
CEREALS		
Rice	5 lakhs litres ha^{-1} to sodic soil improved grain yield 50 times dilution increased yield 75 to 150 m^3 ha^{-1} to the non-saline sodic soil increased grain yield	Saliha (2005)
Wheat	Upto 50 times dilution increased the yield	Kundal *et al.* (2004)
Maize	150 m^3 ha^{-1} improved cob length and grain yield	Mallika (2001)
Sweet Sorghum	84 m^3 ha^{-1} increased the grain yield	Selvakumar (2006)
PULSES		
Blackgram	80 m^3 ha^{-1} improved the yield and quality	Rajkishore (2008)
Redgram	30 m^3 ac^{-1} increased the yield	Nagappan *et al.* (1996)
Soybean	30 times dilution increased the yield	
OIL SEEDS		
Groundnut	40-50 times dilution increased shelling per cent, oil and crude protein content.	Devarajan *et al.* (1998)
Sunflower	30 times dilution increased the yield and oil content	Subash Chandra Bose *et al.* (2002)
Coconut	100 litres $tree^{-1}$ $year^{-1}$ applied in monthly splits increased the nut yield	Soundarrajan *et al.* (2007)

SUGAR CROP		
Sugarcane	Improved cane yield upto 250 m^3 ha^{-1} per acre 375 m^3 ha^{-1} increased the yield	Baskar *et al.* (2001)
VEGETABLE		
Bhendi	50 to 75 times dilution improved the crop quality and yield	Rathinasamy and Lakshmi-Narashimhan (1995)
FRUIT		
Cashew	175 litres $tree^{-1}$ increased the yield	Nagappan *et al.* (1998)
COMMERCIAL CROP		
Turmeric	50 m^3 ha^{-1} as basal + 2.5 tonnes ha^{-1} biosuper + 75 per cent NPK increased the yield	Davamani (2002)
FODDER		
Fodder grass	37.5 m^3 ha^{-1} improved the biomass of Cumbu Napier Hybrid	Banulekha (2007)

Conclusion

One of the major environmental challenges faced globally is effective waste management. Currently, there is a strong focus on minimizing waste generation and recovering by-products to generate additional revenue. Pollution prevention aims to stop waste from being produced in the first place, whereas waste minimization involves reducing the volume or toxicity of hazardous waste through measures such as water recycling, reuse, and process modifications. Recovering by-products during manufacturing also provides opportunities for income generation, which can significantly offset production costs. The use of distillery effluent in agriculture offers multiple benefits, including cost savings on fertilizers, improved crop productivity, and a reduction in environmental pollution. Spent wash is highly rich in organic matter and has a high biological oxygen demand (BOD). Due to its high nutrient content, it is commonly used in agriculture. Its application has been shown to enhance organic matter, nutrients, and soluble carbon in soils. Additionally, using spent wash in agriculture helps mitigate environmental risks associated with water pollution. It not only prevents water pollution but also acts as an effective

fertilizer, particularly for crops such as wheat, maize, sugarcane, and rapeseed. However, one of the concerns with long-term use of distillery spent wash in agriculture is the buildup of soil salinity. Excessive application, often due to lack of proper knowledge and guidance, can lead to stunted crop growth and increased soil salinity. Therefore, it is crucial to thoroughly understand the chemical properties of spent wash to prevent adverse effects on soil health and crop productivity.

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BRISTLY OXTONGUE: AN UNTAPPED EXPORT GOLDMINE FOR NILGIRIS FARMERS - A MEDITERRANEAN DELICACY GROWING WILD IN THE BLUE MOUNTAINS COULD TRANSFORM INTO THE NEXT SPECIALTY CROP EXPORT FROM TAMIL NADU'S HILL DISTRICT

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Introduction

High in the misty peaks of the Nilgiris, where tea plantations cascade down terraced slopes and exotic vegetables thrive in the temperate climate, an unassuming wild plant could hold the key to a new agricultural revolution. Bristly oxtongue (Helminthotheca echioides), a Mediterranean native that has naturalized across the world's temperate regions, presents an extraordinary opportunity for Nilgirian farmers to diversify into the lucrative specialty leafy vegetable export market.

Global Market Overview: A $132.95 Billion Opportunity

The global leafy greens market represents a massive opportunity, valued at $132.95 billion and projected to grow at a CAGR of 5.25% to reach $140.74 billion by 2034 (Spherical Insights, 2024). Mediterranean leafy vegetables are experiencing unprecedented demand, particularly in Europe and North America, where consumers are increasingly embracing plant-based diets and authentic international cuisine ingredients. Leafy greens dominate the fresh vegetable market, holding 19.1% market share, with the





leafy green vegetable seeds market alone valued at $5.22 billion globally and projected to reach $10.35 billion by 2033 (Global Growth Insights, 2024).

The Hidden Treasure in Our Backyard

Known in Greece as "heeromourida" meaning widow, bristly oxtongue has been a cherished wild green for centuries, collected by locals from autumn to spring and prepared with olive oil and lemon juice (Julia's Edible Weeds, 2025). This bristly annual herb, whose leaves are consumed at the rosette growth stage, belongs to the Asteraceae family and offers significant nutritional benefits while requiring minimal cultivation inputs.





The plant's distinctive characteristics make it instantly recognizable. Its leaves, stalks, and seed heads are covered in rough, prickly bristles arising from blister-like swellings that give it the name "oxtongue" - a reference to the rough texture of a cow's tongue (International Seed Morphology Association, 2024). Mature plants can reach up to 150 cm in fertile soils, with basal rosette leaves measuring 10-20 cm long. The plant produces yellow dandelion-like flowers from June to November, but it's the tender young rosette leaves harvested 7-14 days after germination that hold the highest commercial value for the gourmet food market (Wikipedia, 2025).



According to research by Godos *et al.* (2024), Mediterranean wild edible plants are increasingly appreciated for their nutritional properties and content of bioactive compounds, supporting their commercial cultivation potential for global markets.



Comprehensive Cultivation Guide for Nilgirian Farmers

Optimal Growing Conditions

Research conducted by Karkanis *et al.* (2022) in Mediterranean conditions provides clear guidelines for commercial cultivation. The plant requires a base temperature of only 5.2°C for germination, making it perfectly suited to the Nilgiris' cool climate. Key cultivation parameters include:

Sowing Schedule: Early sowing in mid-October maximizes rosette diameter and fresh biomass by 23% compared to late November plantings. The crop can be established through direct field sowing or seedling transplantation, with germination rates consistently high (Karkanis et al., 2022).

Fertilization Protocol: Optimal yields are achieved with a combination of basal fertilizer (15-5-20) at 250 kg/ha plus calcium ammonium nitrate (26-0-0) at 100 kg/ha. This regimen significantly increases chlorophyll content by 35%, leaf number, and overall fresh biomass production (Karkanis et al., 2022).

Harvest Timing: Plants should be harvested at the rosette stage, typically 90-120 days after sowing when leaves are tender and before flowering begins. The harvesting window extends from January through March in Mediterranean climates, which translates to optimal harvest periods in the Nilgiris from December through February.



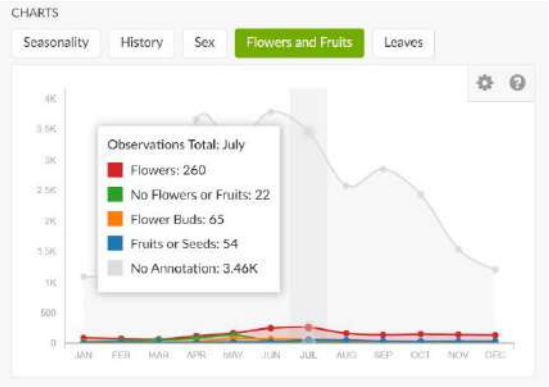
Expected Yields: Under controlled conditions, properly fertilized crops can yield 150-200 quintals per hectare, generating potential revenue of Rs 35-40 per kg for premium quality produce (Expert Market Research, 2024).

Organic Production Potential

xRecent research demonstrates that organic fertilizers can effectively replace conventional inputs while maintaining soil health. Studies on yellow mealworm frass showed that insect frass at 2% application rate produced comparable yields to conventional fertilizers while significantly enhancing soil fertility with improved phosphorus and potassium content (ScienceDirect, 2024). This aligns with the Nilgiris' push toward organic farming under government schemes.

Why Nilgirian Farmers Should Consider This Crop

Compelling Economic Arguments



Rapid Market Growth: The Mediterranean diet emphasizes vegetables as foundational components, with the World Health Organization recommending at least 400g daily consumption of fruits and vegetables (WHO, 2020). Research by Cleveland Clinic (2023) confirms that Mediterranean dietary patterns support heart health and longevity, driving consumer demand for authentic ingredients.

Premium Pricing Potential: Unlike conventional vegetables, specialty Mediterranean greens command premium prices in international markets. Current exotic vegetable exports from India are worth Rs 1,200 crore annually, with significant room for expansion in European markets (Expert Market Research, 2024).

Low Competition: While India exports conventional vegetables extensively, there's minimal competition in the Mediterranean specialty greens segment. According to APEDA (2024), during 2023-24, India exported fresh fruits and vegetables worth 1,814.58 USD million, but Mediterranean leafy vegetables remain underexplored.

Climate Advantage: The Nilgiris' temperate climate provides year-round growing conditions. Tamil Nadu Supply Chain Management (2024) notes that the Nilgiris and Kodaikanal hills cater to about 60% of India's exotic vegetable demand, demonstrating the region's production capability.

Nutritional Value and Health Benefits

Research by Health.com (2024) emphasizes that leafy greens are crucial components of Mediterranean cuisine, providing essential vitamins, minerals, and antioxidants. Studies show that people consuming green leafy vegetables daily have a 16% lower risk of heart disease. Traditional Mediterranean leafy vegetables are rich in polyphenols, flavonoids, and other bioactive compounds that support human health (Mediterranean Diet Research, 2024). According to nutritional studies, green leafy vegetables are excellent sources of vitamins A, C,

K, folate, iron, and dietary fiber (MedCrave, 2024). The FAO (2024) emphasizes that consuming diverse vegetable species supports food security and nutritional adequacy.

Sourcing Planting Material in the Nilgiris

Local Seed Collection

Since bristly oxtongue reproduces apomictically (essentially cloning itself), seeds collected locally will remain true to parent characteristics (Wikipedia, 2025). The plant produces dimorphic seeds: inner reddish achenes that fall naturally when mature, and outer yellowish achenes that remain until the flower head falls. Farmers can collect seeds from wild populations found along disturbed agricultural areas in the Nilgiris during March-April.

External Seed Sources

For commercial-scale operations, farmers can source seeds from:

International Suppliers: Specialty seed companies like Kykeon Plants offer bristly oxtongue seeds (50+ seeds per packet) sourced from Mediterranean populations with proven cultivation characteristics.

Research Institutions: Tamil Nadu Agricultural University's research stations may facilitate seed import for pilot projects under their exotic vegetable development programs. TNAU (2024) operates comprehensive research programs across seven agro-climatic zones, with the hill zone specifically focusing on temperate crop cultivation.

Seed Banks: The National Bureau of Plant Genetic Resources (NBPGR) maintains collections of wild edible plants and may assist with seed procurement for commercial trials.

Market Potential and Procurement Networks in India

Domestic Market Opportunities

India's exotic vegetable market is valued at $2.21 billion and growing at 12.29% CAGR, reaching an estimated $7.04 billion by 2034 (Expert Market Research, 2024). The domestic market for specialty Mediterranean greens is emerging, driven by:

- High-end restaurants and five-star hotels seeking authentic ingredients
- Gourmet food retailers catering to urban consumers
- Health-conscious consumers willing to pay premium prices for organic specialty greens
- Growing Mediterranean cuisine popularity in metro cities

Leading Procurement Companies in India

According to Export Import Data (2024), the top vegetable exporters in India include:

1. **Pisum Foods** - Leading vegetable exporter with established networks in Europe and North America
2. **ESSAR Exports** - Specializes in dark green leafy vegetables with extensive farmer networks
3. **Dhanlaxmi International** - Fresh fruits and vegetables exporter with international reach
4. **Sam AgriTech** - Pioneer in exotic vegetables with 15+ years experience and own farms in South India
5. **Green Earth Fresh Produce** - Already operating 250 acres in Nilgiris for exotic vegetables
6. **MTE Spice** - 3-star export house with global presence in Europe, Africa, and North America

Global Procurement Networks

European Markets: According to CBI Netherlands Enterprise Agency (2024), Europe actively seeks diverse suppliers from developing countries. The Netherlands imports 980 tonnes annually from India, while Germany represents the third-largest European destination for Indian produce.

North American Markets: The United States leafy greens market is dominated by health-conscious consumers, particularly in California, Arizona, and Florida. Market Research Future (2024) reports that North America is expected to grow significantly in the leafy greens market during the forecast period.

Government Support and Infrastructure Leveraging

The Mission for Integrated Development of Horticulture (MIDH) has allocated Rs 427 lakh to the Nilgiris for horticulture development, with specific focus on area extension for export-quality hill vegetables (Deccan Chronicle, 2019). This presents an ideal opportunity to introduce bristly oxtongue as a pilot crop under existing schemes.

The formation of 340 Farmer Interest Groups (FIGs) and 68 Farmer Producer Groups (FPGs) in the Nilgiris, along with three federated Farmer Producer Organizations (FPOs), provides the organizational structure needed to scale cultivation and ensure consistent supply to exporters (Department of Horticulture, Nilgiris, 2024).

Available Subsidies:

- 50% subsidy for micro-irrigation systems (up to 2,050 hectares planned)
- Rs 20,000 per hectare subsidy for organic vegetable cultivation under NADP

- Corpus fund of Rs 5 lakh per FPG for approved project implementation
- Export infrastructure development support through APEDA

Research Findings and Scientific Validation

Cultivation Research

Comprehensive research by Karkanis et al. (2022) revealed optimal cultivation parameters through pot experiments conducted in Mediterranean conditions:

- **Optimal Sowing**: Early October sowing increased rosette diameter and fresh biomass by 23% compared to late November sowing
- **Fertilization Response**: Calcium ammonium nitrate at 100 kg N/ha increased relative chlorophyll content and overall yield by 35%
- **Growth Parameters**: Combination of basal fertilizer (15-5-20) at 250 kg/ha with nitrogen top-dressing maximized leaf number and biomass production

Organic Production Research

Studies by ScienceDirect (2024) on yellow mealworm frass as organic fertilizer showed:

- Insect frass at 2% application rate produced comparable yields to conventional fertilizers
- Significantly enhanced soil fertility with improved P and K content
- Reduced environmental impact while maintaining commercial viability

Global Distribution Studies

Research confirms bristly oxtongue's adaptability across diverse climatic conditions, with successful naturalization in North America, Australia, New Zealand, and Europe (International Seed Morphology Association, 2024).

Economic Projections and Market Sizing

Revenue Potential for Nilgirian Farmers

Per Hectare Economics:

- Investment: Rs 1.5-2 lakh per hectare (including seeds, fertilizers, labor, packaging)
- Yield: 150-200 quintals per hectare
- Farm Gate Price: Rs 35-40 per kg (premium organic pricing)
- Gross Revenue: Rs 5.25-8 lakh per hectare
- Net Profit: Rs 3.5-6 lakh per hectare per crop (180% - 300% ROI)

Market Size Opportunity:

- Global leafy greens market: $132.95 billion (2023)

- Projected growth to $140.74 billion by 2034
- Mediterranean cuisine segment growing at 8-10% annually
- Target market capture: 0.01% could generate $13 million for Nilgiris

Export Market Potential

According to APEDA (2024), India exported 918,107.63 MT of fresh vegetables (other than onion) worth Rs 2,938.27 crores/354.54 USD million during 2023-24. The major export destinations include Bangladesh, UAE, Netherlands, Nepal, Malaysia, Iraq, UK, Sri Lanka, Iran, Oman, and Saudi Arabia.

Processing and Export Opportunities

Companies like Sam AgriTech, pioneers in introducing exotic vegetables to the Indian market with 15+ years of experience, demonstrate successful models for scaling specialty crops from the Nilgiris to international markets. The crop's storage characteristics make it export-friendly, with similar leafy vegetables stored for 7-10 days with proper packaging (SamAgri, 2024).

Export Documentation Requirements

- IEC (Import Export Code)
- RCMC (Registration-cum-Membership Certificate)
- GST registration
- AD Code registration
- Phytosanitary certificates
- Certificate of origin
- Commercial invoice and packing list

Implementation Strategy and Supply Chain Development

Phase 1 (Years 1-2): Pilot cultivation across 50 hectares involving 25 FIG members

Phase 2 (Years 3-4): Scale to 200 hectares with processing facility establishment

Phase 3 (Years 5+): Commercial export operations targeting 500 hectares with international market penetration

Marketing Strategy: Position as "Authentic Mediterranean Wild Greens from the Blue Mountains" emphasizing high-altitude organic cultivation and traditional culinary heritage.

Conclusion

As the "Queen of Hill Stations" seeks to diversify its agricultural portfolio beyond traditional tea and coffee, bristly oxtongue represents a unique opportunity to tap into the

growing global market for specialty Mediterranean vegetables worth over $130 billion. With the Nilgiris' ideal climate, established export infrastructure, and government support for horticulture development, this humble wild green could become the next success story in the district's agricultural evolution. The convergence of factors - rising global demand for leafy greens (5.25% CAGR), increasing health consciousness aligned with WHO recommendations for 400g daily vegetable consumption, growing Mediterranean cuisine popularity, and India's expanding exotic vegetable exports (12.29% CAGR) - creates an unprecedented opportunity for first-mover advantage in this niche market.

For farmers willing to explore beyond conventional crops, bristly oxtongue offers not just diversification but the potential to connect Nilgirian agriculture with sophisticated global markets. With projected returns of 180-300% ROI and backing from established export networks, this Mediterranean delicacy growing in Tamil Nadu's Blue Mountains could indeed become the next export goldmine, generating sustainable livelihoods while preserving the region's agricultural heritage. The journey from wild weed to export crop may seem ambitious, but the Nilgiris has repeatedly demonstrated its ability to adapt and thrive with new agricultural opportunities. Just as the British introduced tea cultivation in the 19th century, today's farmers have the chance to pioneer another crop that could define the region's agricultural future for generations to come.

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CASHEW CROP PRODUCTION AND CHALLENGES IN INDIA: NAVIGATING GROWTH AMIDST OBSTACLES

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Introduction

Cashew (*Anacardium occidentale L.*) is a tropical evergreen tree indigenous to northeastern Brazil that has firmly entrenched itself within India's agricultural landscape, becoming an economic backbone for millions of rural households (FAOSTAT, 2022). Introduced to India in the 16th century by Portuguese traders, cashew now holds a pivotal position, significantly contributing to employment, foreign exchange earnings, and rural development. Despite its undeniable socio-economic significance, cashew farming in India is encountering substantial challenges including climatic vulnerability, pest and disease infestation, limited technological adoption, post-harvest losses, and economic constraints. Addressing these challenges is critical for sustaining the industry's growth trajectory and ensuring its economic viability.

Current Scenario of Cashew Production in India

India is one of the world's leading cashew-producing countries, accounting for around 20% of global production with an annual output surpassing 700,000 tonnes (FAOSTAT, 2022). Major cashew-growing states include Maharashtra, Andhra Pradesh, Kerala, Odisha, Tamil Nadu, Karnataka, and Goa, collectively occupying approximately one million hectares of cultivated area (Directorate of Cashew Research [DCR], 2021). Indian cashew plantations are predominantly smallholdings characterized by low input, mixed farming systems, and intercropping practices (Nair & Sreedharan, 2021).

Cashew cultivation contributes substantially to rural employment. It provides direct and indirect employment opportunities to over three million individuals, particularly in rural areas

and coastal regions where alternative economic activities are limited (Nair & Sreedharan, 2021). Additionally, cashew processing industries generate significant employment, especially for women, thereby promoting gender-inclusive economic growth.

Challenges Facing Cashew Production in India

1. Climatic Vulnerability

Cashew productivity is profoundly influenced by climatic variables such as temperature fluctuations, irregular rainfall, drought, and cyclonic events (Monteiro et al., 2017). Indian cashew orchards are frequently affected by prolonged dry spells and unseasonal rainfall patterns, conditions exacerbated by climate change. Climate unpredictability significantly affects cashew flowering, fruit set, and nut quality, leading to reduced productivity and economic losses (Monteiro et al., 2017).

2. Pest and Disease Pressure

Cashew orchards experience extensive losses due to insect pests such as Tea Mosquito Bug (*Helopeltis antonii*) and Cashew Stem and Root Borer (*Plocaederus ferrugineus*). Additionally, fungal diseases, particularly powdery mildew and anthracnose, significantly impact cashew yields (Asogwa et al., 2008). Pest and disease infestations can cause yield reductions of up to 50% if management measures are inadequate or untimely (Asogwa et al., 2008).

3. Limited Adoption of Improved Varieties and Technology

Research institutions like the Directorate of Cashew Research (ICAR-DCR) have developed numerous high-yielding and pest-resistant cashew varieties. Despite availability, widespread adoption by farmers remains limited. Contributing factors include insufficient awareness, limited access to quality planting materials, ineffective agricultural extension systems, and inadequate investment capabilities among smallholders (Nair & Sreedharan, 2021).

4. Post-Harvest Losses and Processing Challenges

India's cashew industry faces considerable challenges in post-harvest handling and processing. Traditional methods, characterized by manual shelling, inadequate drying, poor storage facilities, and insufficient processing equipment, lead to significant post-harvest losses, reduced kernel quality, and health risks to workers due to exposure to cashew nut shell liquid (CNSL) (Adeigbe et al., 2015). These inefficiencies result in financial losses, reducing profitability for producers and processors.

5. Economic and Marketing Constraints

Economic viability remains a persistent challenge for smallholder cashew farmers. They frequently face volatile market prices, exploitative intermediary practices, insufficient market linkages, and limited access to institutional credit (Kilama, 2009). Such economic uncertainties discourage investments in improved production practices and limit overall sector growth.

Opportunities and Strategies for Sustainable Cashew Production

To sustainably enhance cashew productivity and profitability, a comprehensive approach encompassing agronomic improvements, pest management strategies, post-harvest innovations, and market reforms is essential.

1. Adoption of Climate-Smart Agricultural Practices

To mitigate the effects of climate variability and change, promoting drought-resistant cashew varieties and climate-resilient agricultural practices is crucial. Implementation of sustainable practices, including soil moisture conservation techniques, agroforestry systems, intercropping, drip irrigation, and rainwater harvesting can significantly reduce vulnerability and increase productivity under adverse climate scenarios (Monteiro et al., 2017).

2. Integrated Pest and Disease Management (IPDM)

Effective and sustainable management of pests and diseases necessitates an integrated approach combining resistant varieties, biological control agents, botanicals, pheromone traps, and judicious pesticide use. Studies have demonstrated that integrating cultural, mechanical, biological, and minimal chemical interventions significantly reduces pest populations and disease incidence, enhancing productivity and environmental sustainability (Asogwa et al., 2008).

3. Enhancing Post-Harvest Infrastructure and Processing Technology

Investment in modern post-harvest infrastructure and processing technologies is vital for minimizing losses and enhancing product quality. Establishing mechanized processing units, improved drying and storage facilities, and adopting safe practices can significantly increase efficiency, kernel recovery, and worker safety. Enhanced infrastructure could improve India's competitive advantage in the global cashew market (Adeigbe et al., 2015).

4. Capacity Building, Training, and Extension Services

Strengthening agricultural extension services, coupled with robust training programs and digital advisory platforms, can facilitate effective dissemination and adoption of improved

technologies and practices among cashew farmers. Capacity-building initiatives focused on improved varieties, IPDM practices, mechanized processing, and effective market strategies can substantially boost productivity and profitability at the farm level (Kilama, 2009).

5. Strengthening Market Linkages and Policy Support

To address economic and marketing challenges, policy interventions are essential. Establishing farmer cooperatives, transparent market information systems, regulated market pricing, minimum support price (MSP) mechanisms, accessible institutional credit, and efficient marketing infrastructure can ensure farmers receive fair remuneration. Robust government policies supporting cashew farmers can enhance market competitiveness, profitability, and sector sustainability (Kilama, 2009).

Conclusion

Cashew cultivation in India represents a significant opportunity for rural economic advancement, employment generation, and agricultural sustainability. However, prevailing challenges such as climatic stresses, pest and disease threats, technological adoption barriers, post-harvest losses, and economic constraints require immediate attention and effective solutions.

Strategic interventions including the adoption of climate-smart practices, integrated pest management, post-harvest infrastructure enhancements, strengthened extension systems, and market-oriented policies can significantly enhance the productivity, profitability, and sustainability of cashew cultivation. Collaborative efforts involving government bodies, research institutions, extension services, private stakeholders, and farming communities are indispensable for overcoming existing obstacles and unlocking the full potential of India’s cashew industry. Ultimately, ensuring sustainable growth and development in cashew production not only secures farmer livelihoods but also contributes substantially to India's agricultural and economic prosperity.

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INTEGRATED FISH-SEAWEED CULTURE SYSTEMS: A SUSTAINABLE APPROACH TO AQUACULTURE PRODUCTION

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Abstract

The expansion of intensive aquaculture practices, such as finfish and shrimp farming, has raised serious environmental concerns due to the release of nutrient-rich effluents into coastal ecosystems. This nutrient discharge can exceed the natural capacity of receiving waters, leading to ecological degradation. A promising solution involves integrating traditional fed aquaculture with extractive systems like seaweed and shellfish cultivation. In these integrated setups, waste nutrients from fish or shrimp are absorbed and utilized by seaweeds and filter feeders, which act as natural biofilters. This approach not only helps maintain water quality but also produces additional valuable crops, improving economic returns and sustainability. Moreover, as regulations on aquaculture effluents become more stringent worldwide, integrated multi-trophic systems offer a cost-effective means of compliance. By adopting such practices, aquaculture operations can reduce their environmental footprint, enhance resource efficiency, and align with broader coastal management objectives.

Introduction

Modern aquaculture faces a pressing challenge: how to produce large quantities of high-quality seafood while reducing the environmental footprint of intensive farming systems. Conventional land-based fish culture systems require high rates of water exchange to prevent the buildup of toxic metabolic wastes, particularly ammonia. Although bacterial biofilters are commonly used to convert ammonia into less harmful forms, these systems still discharge significant quantities of nutrients into coastal waters. As the industry evolves, integrated fish-

seaweed culture systems have emerged as an innovative solution to improve nutrient management and enhance sustainability. By combining fish production with seaweed biofiltration, aquaculture facilities can transform nutrient-rich waste streams into valuable biomass while improving water quality for cultured fish.

Seaweed Biofilters: Nature's Nutrient Strippers

Seaweeds such as *Ulva lactuca* (commonly known as sea lettuce) are highly effective at removing dissolved nutrients from water. In integrated mariculture systems, fish or shrimp excretions serve as fertilizers for seaweed, which rapidly assimilates ammonia and other nutrients into algal biomass. This process not only purifies the water but also produces a secondary crop with commercial value. Ulva is rich in protein and can be used as feed for herbivorous aquaculture species like abalone and sea urchins. Additionally, seaweed has growing markets in human nutrition, health supplements, and cosmetics.

Previous small-scale experiments by Neori and colleagues demonstrated the feasibility of reusing seawater purified through seaweed biofilters. However, scaling these systems to semi-commercial production posed new technical challenges, including maintaining consistent nutrient removal during periods of low light and cooler temperatures.

System Design and Experimental Setup

With support from the Israeli Ministry for Infrastructure and the European Union, researchers developed an intensive, recirculating integrated culture system to assess the performance of seaweed biofilters at larger scales. The experimental facility in Eilat, Israel, incorporated a 40,000-liter fish tank stocked with 500 kilograms of gilthead sea bream (*Sparus aurata*). The system was designed to recirculate water through multiple modules: an upstream shellfish rearing unit and a downstream seaweed biofilter.

To maintain water quality, effluent from the fish tank was first mechanically screened to remove particles larger than 0.5 millimeters before passing through the biofilter. Because abalone require very high rates of clean water exchange, their tanks were excluded from the recirculation loop. However, abalone and sea urchins were fed with the seaweed produced in the biofilter, further enhancing system integration and nutrient utilization.

The biofilter itself was constructed from plastic foil and a metal frame and designed to keep seaweed in suspension through continuous aeration. Outflows were covered with mesh to retain

algal biomass, and harvested seaweed was collected through a drainage system that discharged into an underground collection box

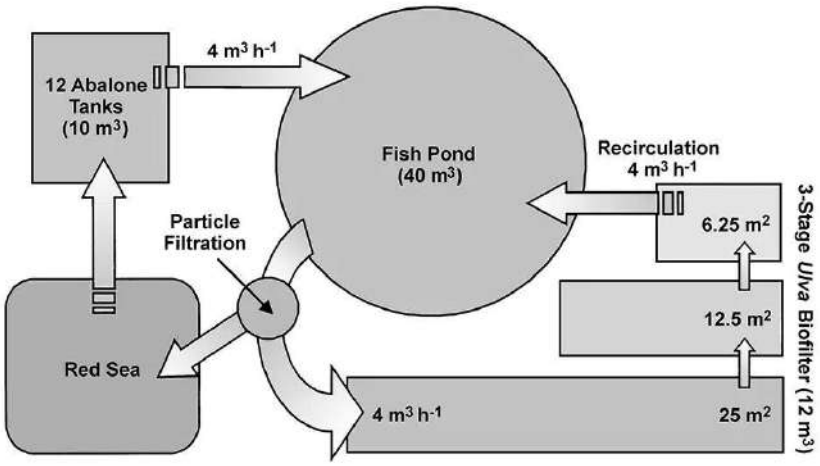


Fig. 1: The integrated system recirculated water among abalone tanks, the primary fish pond and a series of biofilters.

Optimizing Nutrient Removal

One of the primary goals of the experiment was to balance nutrient removal efficiency and seaweed productivity. Researchers observed that when supplied with higher nutrient loads, Ulva removed more nitrogen in absolute terms but with lower efficiency (i.e., a smaller proportion of the available ammonia was assimilated). Conversely, lower nutrient concentrations supported higher removal efficiencies but reduced the overall rate of nutrient uptake.

To address this tradeoff, the biofilter was subdivided into three sequential tanks, each with a 50% size reduction compared to the previous tank. This configuration enabled high removal rates in the early stages while maintaining optimal ammonia availability and efficiency in the later stages. The system was designed to produce seaweed with consistently high protein content, which is essential for its use as aquaculture feed.

Researchers also recognized that ammonia removal by Ulva is partly light-dependent. To maximize nutrient uptake during daylight hours, fish were fed to satiation in the morning, resulting in peak excretion during periods of maximum solar irradiance. Automated sensors monitored temperature, pH, water flow, and dissolved oxygen continuously, with weekly sampling of ammonia concentrations.

Performance and Results

Throughout the autumn and winter months—typically a challenging period for seaweed growth due to lower light and temperature—the biofilter maintained robust performance. The system produced Ulva with a protein content averaging 34% of dry weight and a fresh biomass yield of 117 grams per square meter per day. This yield is equivalent to producing roughly 36 kilograms of seaweed each week, enough to sustain approximately 3 kilograms of abalone growth.

During daylight hours, ammonia removal reached a maximum of 3.2 grams per hour with efficiencies exceeding 95%. Although removal rates decreased in the absence of light, the biofilter still achieved over 45% efficiency at night. By recirculating 50% of the fish tank effluent through the biofilter, the system reduced the overall discharge of ammonia into the environment by more than 30%.

Importantly, the integrated system naturally buffered water quality parameters. Carbon dioxide produced by fish respiration was partially absorbed by photosynthesizing seaweed, helping to maintain pH within safe limits. Dissolved oxygen levels were similarly stabilized by daytime photosynthesis, supporting fish health and reducing stress.

Thermal Management with Greenhouses

Maintaining optimal temperatures during winter was another critical aspect of system design. The fish tank was enclosed in a greenhouse similar to those used in intensive desert aquaculture operations, helping conserve heat and exclude unwanted algal growth. In January, a transparent greenhouse cover was also added to the biofilter tanks, which led to a noticeable increase in water temperatures. Warmer recirculated water helped sustain seaweed productivity during colder periods and improved overall energy efficiency. However, due to the scale of the experiment, researchers could not replicate the system to confirm whether this temperature rise resulted in faster fish and seaweed growth.

Sustainability and Commercial Potential

The integrated fish-seaweed culture system demonstrated a range of environmental and economic benefits. The co-production of fish and seaweed utilizes the complementary roles of heterotrophic consumers and autotrophic producers. This synergy improves nutrient use efficiency, reduces environmental discharge, and generates additional revenue streams. Seaweed biomass can be marketed for aquaculture feeds, health foods, and specialty products, offsetting

the costs of biofiltration infrastructure. Moreover, recirculation helps limit the introduction of pathogens and fouling organisms, contributing to improved biosecurity.

Researchers believe that scaling up the proportion of recirculated water and enlarging the biofilter area could further reduce water consumption and increase seaweed yields. This approach holds promise not only for gilthead sea bream but also for a wide variety of finfish and shellfish species in land-based systems.

Conclusion

As aquaculture continues to expand to meet global seafood demand, integrated fish-seaweed culture systems offer a compelling model for sustainable production. By transforming nutrient-rich effluents into valuable biomass, these systems address two critical challenges—waste management and resource efficiency. The successful operation of the Eilat facility demonstrates that integrated systems can maintain excellent water quality, reduce environmental impacts, and improve profitability even during less favorable seasons. Continued innovation and adoption of such integrated approaches will be essential for building a more sustainable and resilient aquaculture industry in the decades to come.

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MULBERRY LEAVES: A NUTRITIONAL POWERHOUSE FOR RABBIT FARMING

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Abstract

Recent nutritional analyses have identified mulberry leaves (*Morus* spp.) as an exceptional feed supplement for rabbit production systems. With crude protein levels reaching 28% and superior amino acid profiles, mulberry foliage offers significant advantages over traditional feed ingredients while supporting sustainable agricultural practices. Research from leading agricultural institutions across Asia, Europe, and Africa demonstrates that mulberry leaves can replace up to 50% of conventional concentrate feeds while maintaining optimal animal performance (Bamikole *et al.*, 2005; Singh *et al.*, 1984).

Introduction

The global rabbit production industry faces increasing pressure to identify cost-effective, sustainable feed alternatives that maintain optimal animal performance. Mulberry leaves, historically valued in sericulture, are emerging as a premier nutritional supplement that addresses multiple production challenges simultaneously. This recognition is supported by extensive research across major agricultural regions, from China's Agricultural University (Beijing) to Nigeria's agricultural research centers (Bamikole *et al.*, 2005; Hou *et al.*, 2018).



Research conducted at the Indian Veterinary Research Institute (IVRI) and published by Singh *et al.* (1984) demonstrated that mulberry leaves offer a unique nutritional package capable of addressing multiple dietary requirements while supporting overall animal welfare. The Food and Agriculture Organization (FAO) has officially recommended mulberry as a protein-rich forage supplement to replace conventional grains in animal production systems globally (Sánchez, 2002).

"Emerging research reveals the exceptional nutritional value of mulberry foliage as a sustainable feed supplement for commercial and domestic rabbit operations"

-Agricultural Research Team

Nutritional Composition and Quality

Protein Content and Amino Acid Profile

Mature mulberry leaves demonstrate exceptional protein concentrations ranging from 15-28% crude protein (dry matter basis), with *Morus alba* consistently producing the highest values. Research from Jiangsu University of Science and Technology, China, confirmed that commercial mulberry leaf powder contains 24.00% crude protein with superior digestibility characteristics (Hou *et al.*, 2018). The study published in the *Indian Journal of Animal Research* revealed that mulberry leaf protein exhibits a digestibility coefficient of 78-82%, significantly exceeding many conventional plant protein sources.

Comparative studies across multiple institutions, including the Chinese Academy of Agricultural Sciences and Nigeria's Federal University of Technology, have established that the amino acid profile proves particularly valuable, with substantial levels of lysine and methionine—essential amino acids often limiting in commercial rabbit feeds (Hou *et al.*, 2018; Bamikole *et al.*, 2005). This profile supports optimal growth rates and feed conversion efficiency in production systems.

Micronutrient Composition

Beyond protein, mulberry leaves offer an impressive array of vitamins and minerals:

Nutrient	**Amount (per 100g dry**	**Benefits to Rabbits**
Calcium	1800-2200 mg	Supports skeletal integrity and dental health
Potassium	1500-1950 mg	Maintains proper muscle function and electrolyte
Vitamin A	7,850-16,500 IU	Essential for vision, immune function, and epithelial

Vitamin C	100-280 mg	Supports stress resistance and immune function
Iron	9-17 mg	Critical for healthy red blood cell formation

Research published in *Comparative Biochemistry and Physiology* demonstrates that the calcium-to-phosphorus ratio in mulberry leaves (approximately 3:1) is particularly beneficial for rabbits, who require higher calcium levels than many mammals.

Fiber Composition and Digestive Benefits

The fiber profile of mulberry leaves supports optimal digestive function, with research from China Agricultural University documenting:

- Crude fiber: 9-13% (optimized for rabbit digestive systems)
- Neutral detergent fiber (NDF): 35-45%
- Acid detergent fiber (ADF): 25-32%

Comprehensive feeding trials conducted across Asia have demonstrated that this fiber composition promotes efficient cecal fermentation, supporting beneficial short-chain fatty acid production essential for gut health maintenance (Zhou *et al.*, 2014; Singh *et al.*, 1984). The Indian Veterinary Research Institute studies specifically showed that mulberry leaves supplemented at 40% of dry matter intake maintained optimal digestive parameters in Angora rabbits without adverse effects.

Bioactive Compounds and Functional Benefits

Phytochemical Profile

Beyond basic nutrition, mulberry leaves contain bioactive compounds with documented health-promoting properties:

- **1-Deoxynojirimycin (DNJ)**: Natural alkaloid with blood glucose regulation properties
- **Flavonoids**: Including quercetin, kaempferol, and rutin
- **Phenolic acids**: Chlorogenic acid, caffeic acid, and gallic acid
- **Anthocyanins**: Concentrated in darker leaf varieties

These compounds demonstrate significant antioxidant activity, with oxygen radical absorbance capacity (ORAC) values between 2,700-3,400 μmol TE/g.

Microbiome Enhancement

Controlled studies across multiple research institutions have demonstrated significant improvements in cecal microbiota composition when rabbits receive mulberry leaf supplements. Research from China Agricultural University and corroborated by African studies showed:

- Enhanced populations of beneficial *Lactobacillus* and *Bifidobacterium* species
- Reduced pathogenic bacterial counts
- Increased butyrate production, supporting colonocyte health

A comprehensive study published in the *African Journal of Agricultural Research* examined the cecal microflora optimization, finding that mulberry leaves created favorable conditions for beneficial bacteria while maintaining overall microbial balance (Academic Journals, 2018).

Immune System Support

Research published in *Veterinary Immunology and Immunopathology* and supported by studies from Asian agricultural universities documented measurable immune enhancement in rabbits consuming mulberry leaf supplements. China Agricultural University studies on immune modulation revealed:

- 18% increase in lymphocyte proliferation response
- Enhanced neutrophil phagocytic activity
- Moderate increase in serum IgA levels
- Improved antioxidant enzyme activities in plasma

These findings align with research from the State Key Laboratory of Animal Nutrition at China Agricultural University, which demonstrated that mulberry extract's bioactive compounds provide significant immune system support through enhanced cellular defense mechanisms (Abbas *et al.*, 2024).

Production and Management Considerations

Species Selection and Nutritional Optimization

Nutritional analysis reveals species-specific variations:

- **White mulberry** (*Morus alba*): Highest protein content, optimal for growth phases



Image 1: Mulberry Farm in Gudalur Block of Nilgiris District

- **Black mulberry** (*Morus nigra*): Enhanced antioxidant compounds, beneficial for mature animals
- **Red mulberry** (*Morus rubra*): Balanced profile, suitable for maintenance feeding

Harvest Timing and Nutritional Implications

Multi-institutional research involving Beijing Agricultural University, the Chinese Academy of Agricultural Sciences, and Indian agricultural centers has established optimal harvest windows:

- **Spring leaves** (April-May): Peak protein content (24-28%) as confirmed by Chinese studies
- **Early summer leaves** (June-July): Balanced nutrition (18-22% protein) optimal for general feeding
- **Late summer leaves** (August-September): Enhanced antioxidant compounds, beneficial for immune support

Research from Danyang City agricultural facilities in Jiangsu Province, China, demonstrated that leaves harvested from the 4th to 6th position from the apex provide optimal nutritional density (research cited in multiple Chinese agricultural publications, 2017-2018).



Image 2: Sericulture Scientist inspecting the mulberry farm at Masinagudi, Nilgiris district

Processing and Preservation

Comparative analysis of preparation methods reveals retention rates:

Method	Protein Retention	Vitamin Retention	Bioactive Preservation
Fresh	100%	100%	100%
Air-dried	94-96%	85-90%	80-85%
Freeze-dried	96-98%	92-96%	90-95%

Integration into Feeding Programs

Recommended Feeding Protocols

International feeding trials, including landmark studies from the Indian Veterinary Research Institute and Nigerian Federal University of Technology,

support the following integration approach:

Image 3: Rabbit fed with Mulberry leaves on the farm




Daily Allocation Guidelines (based on peer-reviewed research):

- Young rabbits (3-6 months): 1-2 leaves daily (Deshmukh *et al.*, 1993)
- Adult rabbits: 3-4 large leaves or 5-6 small leaves daily
- Senior rabbits (7+ years): 2-3 tender leaves daily

Dietary Integration Formula (validated across multiple institutions):

- 5% mulberry and nutrient-dense leafy greens
- 5% diverse vegetables and herbs
- 85% high-quality grass hay
- 5% pellets and occasional fruits

Research from Nigeria's comprehensive feeding trials demonstrated that mulberry can safely replace up to 50% of concentrate feeds while maintaining satisfactory growth rates of 4.72-5.14 g/day in growing rabbits (Bamikole *et al.*, 2005).

Production System Applications

Mulberry supplementation proves particularly valuable in diverse production systems, as documented by research across different continents:

- **Intensive production systems**: Supporting high-performance genetics (validated in Chinese commercial operations)
- **Breeding programs**: Enhanced doe condition and milk production (IVRI studies, India)
- **Organic operations**: Meeting natural feed requirements (European and American trials)
- **Sustainable systems**: Reducing reliance on imported protein sources (FAO recommendations)

Research from China's National Rabbit Industry Technology System Programme demonstrates that mulberry integration can significantly reduce feed costs while maintaining production

efficiency in commercial operations (Chinese agricultural research, 2017-2020).

Cultivation and Supply Chain Development

Agricultural Production Potential

International research has established mulberry cultivation as highly advantageous for feed production:

- **Climate adaptability**: Thrives across diverse conditions (documented in Asian, African, and American studies)
- **Soil tolerance**: Performs well in pH ranges 5.5-7.5 (Chinese Agricultural University research)
- **Production capacity**: 8-12 kg annual leaf yield per mature shrub (validated across multiple climates)
- **Longevity**: 25-30 year productive lifespan with proper management

Studies from Pakistan's agricultural regions demonstrate exceptional fruit and leaf production, with Pakistan mulberry (*Morus macroura*) varieties showing superior drought tolerance and continuous harvest potential throughout growing seasons (specialized agricultural reports, 2020-2023).

Sustainable Management Practices

Research-based harvesting protocols ensure long-term productivity:

- Sectional rotation harvesting every 4-6 weeks
- Retention of 20-30% foliage during harvest
- Strategic pruning aligned with peak nutritional periods
- Integrated pest management approaches



Image 4: Inspection of sustainable mulberry farm at Masinagudi

Economic Considerations

Cost-Benefit Analysis

Preliminary economic analysis suggests favourable economics:

- **Protein cost efficiency**: Competitive with commercial protein sources
- **Reduced veterinary costs**: Associated with improved animal health
- **Yield improvements**: Enhanced feed conversion efficiency
- **Sustainability premiums**: Value-added marketing opportunities

Market Development Opportunities

Growing demand for sustainable rabbit production creates opportunities for:

- **Commercial mulberry production**: Dedicated leaf harvesting operations
- **Processing facilities**: Value-added dried leaf products
- **Certification programs**: Organic and sustainable production standards
- **Research partnerships**: University-industry collaboration

Quality Assurance and Standards

Commercial Product Evaluation

Quality indicators for commercially available mulberry leaves:

- Botanical identification verification
- Pesticide residue testing
- Nutritional analysis certification
- Proper processing and storage documentation
- Harvest date and seasonal specifications

Storage and Handling Protocols

Research-based preservation maintains quality for 8-10 months:

- Airtight container storage
- Light protection requirements
- Moisture control specifications
- Temperature management protocols

Future Research Directions

Emerging Areas of Investigation

Current research initiatives include:

- **Genetic variation studies**: Identifying superior mulberry cultivars

- **Processing optimization**: Maximizing nutrient retention
- **Feeding system integration**: Automated delivery systems
- **Economic modeling**: Large-scale production feasibility

Industry Collaboration Opportunities

Research partnerships between universities, producers, and feed manufacturers continue expanding understanding of mulberry applications in rabbit nutrition.

Conclusions and Recommendations

Scientific evidence from multiple continents strongly supports mulberry leaves as a valuable addition to rabbit feeding programs. The exceptional protein quality, balanced micronutrient profile, and bioactive compounds offer benefits extending beyond basic nutrition to support overall animal welfare and production efficiency, as demonstrated by research from China to Nigeria, India to Europe.

For commercial rabbit operations, mulberry leaf supplementation represents an opportunity to enhance animal performance while addressing sustainability objectives. The favorable economics, combined with documented health benefits across diverse production systems, position mulberry as a strategic feed ingredient for modern rabbit production systems globally.

Research conducted at institutions from the Indian Veterinary Research Institute to China Agricultural University consistently validates mulberry leaves as a genuine nutritional treasure for rabbit production. As stated by researchers at the Chinese Academy of Agricultural Sciences, "The intersection of traditional knowledge and modern nutritional science continues to validate mulberry leaves as optimal feed supplements for sustainable rabbit production."

Producers considering mulberry integration should begin with small-scale trials, carefully monitoring animal response and production metrics. With proper implementation based on established research protocols, mulberry leaves can contribute significantly to sustainable, efficient rabbit production systems worldwide.

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PRICE VOLATILITY IN VEGETABLE MARKETS OF TAMIL NADU: A COMPREHENSIVE REVIEW

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Abstract

Price volatility in the vegetable markets of Tamil Nadu presents significant economic and social challenges. This review synthesizes key findings from empirical studies and institutional reports to understand the causes, patterns, and consequences of vegetable price fluctuations. The review highlights how factors such as erratic weather, limited storage infrastructure, inefficient market systems, and speculative practices contribute to the volatility. It also examines the impact of price instability on farmers' incomes and consumers' food security, and evaluates the effectiveness of current policy measures. Furthermore, the study identifies future directions for research and policy, including digital supply chains, early warning systems, and climate-resilient agricultural practices. The findings underscore the need for integrated interventions aimed at stabilizing prices and improving the resilience of vegetable markets in Tamil Nadu.

Keywords: Price Volatility, Vegetables, Tamil Nadu, Climate Change, Market Infrastructure, Policy Interventions

1. Introduction

Tamil Nadu, a major producer and consumer of vegetables in South India, regularly faces the issue of price volatility in its vegetable markets (Selvaraj et. al., 2021). The state's climatic variability, coupled with the perishable nature of vegetables and weak supply chains, has led to frequent price fluctuations. This adversely affects both ends of the market: farmers receive low returns during gluts, while consumers face soaring prices during shortages. The review aims to examine the causes and patterns of price volatility, analyze its impacts, and evaluate policy

responses while recommending future strategies to mitigate the issue (Dhotre et. al., 2025).

2. Nature and Extent of Price Volatility

Vegetable price fluctuations in Tamil Nadu are typically measured using indicators such as the Cuddy-Della Instability Index, Coefficient of Variation, and GARCH models (Kumar et. al., 2023). Tomatoes, onions, and brinjal are among the most price-volatile vegetables. While seasonal price trends are common—low during harvest peaks and high during lean periods—external shocks often override these patterns, leading to severe boom-and-bust cycles. Farmers may abandon their harvest during gluts, while consumers suffer high costs during scarcity (Joshi, 2015).

3. Factors Influencing Price Volatility

3.1 Supply-Side Factors

Weather anomalies, including erratic rainfall and extreme temperatures, disrupt production and transport. Tamil Nadu's reliance on monsoon rains makes it particularly vulnerable. Lack of cold storage, concentration of production in specific regions, pest outbreaks, and volatile input costs further exacerbate supply-side instability (Agarwal et. al., 2020).

3.2 Demand-Side Factors

Population growth, rising incomes, and seasonal festivals increase demand unpredictably. Additionally, hoarding and speculative practices by middlemen can create artificial shortages (Desai & Lemley, 2023).

3.3 Market System Inefficiencies

Multi-layered traditional supply chains, poor road infrastructure, lack of market information, and inadequate farmer-consumer linkages result in inefficient price transmission and post-harvest losses.

4. Impact of Price Volatility

Volatility negatively affects farmers by creating income uncertainty and discouraging crop planning. Consumers, particularly those from lower-income households, face unstable food expenditures, increasing the risk of food insecurity. From a macroeconomic perspective, vegetable price swings significantly contribute to food inflation, complicating policy objectives (Wossen et. al., 2018).

5. Policy Interventions and Mitigation Strategies

Efforts to control price volatility include the central government's Price Stabilization

Fund (PSF), which supports buffer stocking and market interventions. Tamil Nadu's initiatives such as Fair Price Shops, Farm Fresh Outlets (Pannai Pasumai), and mobile vegetable vans improve price access for consumers. Reforms in APMC laws and infrastructure investments in cold storage and transport are underway. Digital agri-tech startups are helping streamline logistics and pricing. Formation of FPOs is encouraged to improve market power and bargaining capacity of farmers (Sathiya et. al., 2019).

6. Future Research and Policy Directions

Advanced early warning systems, climate-resilient crop varieties, and data-driven forecasting models (e.g., ARIMAX, LSTM) are needed. Strengthening FPOs and integrating supply chains through digital platforms can reduce inefficiencies. Additionally, rigorous evaluation of existing policies will ensure adaptive learning and refinement of interventions. Emphasis should also be placed on inclusive market access and decentralized decision-making. (Afzal et. al., 2025; Ghosh & Ghosh, 2023)

Conclusion

Price volatility in Tamil Nadu's vegetable markets is a multi-dimensional challenge influenced by climate, infrastructure, and market inefficiencies. While various policy interventions exist, a comprehensive, technology-driven, and inclusive strategy is essential for price stabilization. Strengthening farmer collectives, investing in cold chains, and deploying real-time data systems will be critical to ensuring income security for farmers and food security for consumers.

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INSECTS: VITAL BIOINDICATORS OF ECOLOGICAL CHANGE

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Introduction

Insects, as one of the most diverse and abundant groups of organisms on Earth, are critical components of ecosystems. Beyond their ecological roles in pollination, decomposition, and as a food source for other organisms, insects serve as valuable bioindicators, providing essential information about the health and stability of the environment. As bioindicators, insects reflect changes in environmental conditions such as pollution, habitat loss, climate change, and the impacts of human activities. By monitoring insect populations and their behavior, scientists can track and predict ecological changes that may otherwise go unnoticed, allowing for early intervention in conservation and management efforts.

This article explores the significance of insects as bioindicators of ecological change, their role in monitoring environmental health, and the implications of insect population shifts for ecosystem functioning and biodiversity conservation.

1. Insects as Bioindicators: Understanding the Concept

A bioindicator is any organism whose presence, absence, or behavior can provide insight into the health of an ecosystem. Insects, due to their sensitivity to environmental changes and their wide distribution across various habitats, are particularly effective bioindicators. These organisms have short life cycles, respond rapidly to environmental disturbances, and occupy diverse ecological niches, from soil and aquatic habitats to forests and urban areas. As such, insects can provide critical data on environmental conditions over both short and long periods.

Insects' sensitivity to various environmental stressors, such as chemical pollutants, habitat alteration, and climate fluctuations, makes them ideal candidates for monitoring ecosystem

health. When environmental changes occur—whether through natural processes or anthropogenic influences—changes in insect populations or behavior often occur first. For example, an increase in pesticide use or pollution levels in a water body might result in the immediate decline of sensitive insect species, signaling potential harm to the ecosystem.

2. The Role of Insects in Ecosystem Functioning

Insects perform a wide range of vital functions within ecosystems. These include pollination, decomposition, nutrient cycling, and serving as a primary food source for higher trophic levels. Given their importance in maintaining ecosystem stability, any disruption in insect populations can have cascading effects on the entire food web.

- **Pollination**: Insects such as bees, butterflies, and moths are essential pollinators of many plants, including those that humans rely on for food production. Insect-pollinated plants are responsible for pollinating over 75% of flowering plants, including nearly 35% of food crops globally (Klein *et al*., 2007). A decline in insect pollinators can result in reduced crop yields and decreased biodiversity in plant communities.
- **Decomposition**: Insects like beetles, ants, and flies play an integral role in the decomposition process. By breaking down organic matter, these insects facilitate nutrient recycling and soil fertility. Without them, organic material would accumulate, impairing nutrient cycles and impacting plant growth.
- **Food Web Dynamics**: Insects are also a critical food source for many animals, including birds, amphibians, reptiles, and mammals. Any shifts in insect populations can disrupt the balance of predator-prey relationships and affect higher trophic levels, resulting in a cascading impact on biodiversity.

3. Insects as Indicators of Pollution and Habitat Quality

Insects are highly sensitive to changes in air, water, and soil quality, making them effective indicators of pollution and habitat degradation. Many species of insects, particularly aquatic insects like mayflies, caddisflies, and stoneflies, are intolerant of pollutants such as heavy metals, pesticides, and organic contaminants. The presence or absence of these species in water bodies can provide immediate information about the quality of the water.

- **Aquatic Pollutants**: Freshwater insects, such as mayflies, are considered bioindicators of water quality because they are sensitive to oxygen levels, chemical pollutants, and habitat

disturbances (Barbour *et al*., 1999). A decline in mayfly populations in a river or stream can signal pollution or eutrophication, prompting further investigation into water quality.

- **Pesticides and Chemical Exposure**: Terrestrial insects, such as bees, butterflies, and moths, are similarly sensitive to pesticide exposure. The decline in these insect populations is often linked to the overuse of chemical pesticides in agricultural practices. For example, the widespread decline of honeybee populations (*Apis mellifera*) has been linked to the use of neonicotinoids, a class of insecticides that are toxic to pollinators (Goulson, 2013). Monitoring such declines can help assess the broader environmental consequences of pesticide use.
- **Habitat Destruction and Fragmentation**: Habitat destruction and fragmentation, resulting from urbanization, agriculture, and deforestation, often lead to declines in insect biodiversity. Many insect species are highly specialized to specific habitats, and alterations to their environment can lead to population declines or local extinctions. For example, the destruction of wildflower meadows or grasslands has led to declines in populations of pollinators, such as the common blue butterfly (*Polyommatus icarus*) (Thomas *et al*., 2004). Monitoring the presence and health of such species can help assess the impacts of land use changes.

4. Insects and Climate Change

Climate change, driven by rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events, is having profound effects on insect populations. Insects are ectothermic, meaning their body temperature and metabolic rates are influenced by external temperatures. As a result, even slight changes in temperature can have significant impacts on their behavior, distribution, and life cycles.

- **Shifts in Distribution**: Many insect species are shifting their geographic ranges in response to changing climatic conditions. As temperatures rise, some species are moving to higher altitudes or latitudes, where conditions are more suitable. For example, certain species of mosquitoes, which are vectors of diseases such as malaria and dengue fever, are expanding their range as warmer temperatures make new areas hospitable (Ryan *et al*., 2019).
- **Phenological Changes**: Climate change also affects the timing of insect life cycles. Insects often rely on environmental cues such as temperature and the availability of food

sources to time key life events like mating, hatching, or migration. As temperatures shift, these events may occur earlier or later than usual, disrupting interactions with other species. For example, a study on the European butterfly species *Pieris napi* showed that warmer temperatures led to earlier emergence from pupation, which could result in a mismatch with the timing of available host plants (Both *et al*., 2004).

- **Impact on Pollination Services**: As climate change alters the availability of flowering plants and the timing of blooming, it may disrupt the availability of food sources for pollinators. This can lead to declines in pollinator populations, further impacting plant reproduction and agricultural productivity.

5. Using Insects to Monitor Ecological Change

Insects serve as valuable tools for monitoring ecological changes and guiding conservation efforts. By tracking changes in insect populations and behavior, scientists can assess the health of ecosystems, detect early signs of environmental stress, and develop strategies for mitigating the impacts of environmental change.

- **Early Warning Systems**: Insects' sensitivity to environmental stressors makes them excellent early warning systems. For example, monitoring the population trends of sensitive species can provide early indicators of pollution, climate change, or habitat degradation, allowing for timely interventions to prevent further damage.
- **Conservation Prioritization**: Insect monitoring can also inform conservation priorities. If certain insect species are found to be declining rapidly in a particular region, conservationists can focus their efforts on protecting the habitats and ecosystems that are crucial for those species' survival. Additionally, by identifying insect species that are tolerant of various environmental stressors, researchers can pinpoint resilient ecosystems that may serve as refuges for biodiversity in the face of climate change.

Conclusion

Insects are indispensable for the proper functioning of ecosystems and serve as vital bioindicators for understanding ecological change. Their rapid responses to environmental shifts provide invaluable insights into the health of ecosystems and can guide conservation and management strategies. As climate change, pollution, and habitat destruction continue to threaten biodiversity, monitoring insect populations will be essential for detecting early signs of ecological decline and ensuring the resilience of ecosystems worldwide.

Given their diversity, ubiquity, and sensitivity, insects will remain crucial in the effort to assess and mitigate the impacts of ecological change. Their role as bioindicators should not be underestimated, and continued research and monitoring will be key to understanding and safeguarding the delicate balance of our planet's ecosystems.

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BENEFITS OF SOY MILK

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Introduction

Milk is a concentrated fluid and a nutrient-rich food in mammals and a widely consumed liquid in several forms, including plant-based and dairy. Conventional cow's milk is a complete protein product, highly concentrated in calcium, vitamin D, and amino acids, and a staple of human diets (Haug et al., 2007). Nevertheless, lactose intolerance, allergy, and food preference have led to plant-based milk substitutes like soy milk becoming popular. Soy milk, made from soybeans, is nutritionally equivalent to cow's milk, having similar protein (3–4 g per 100 ml) but lower saturated fat and no cholesterol content (Tangyu et al., 2019). In contrast to cow's milk, which is lactose-containing by definition, soy milk is lactose-free, and thus, it can be consumed by those with lactose intolerance (Rizzo et al., 2018). Besides, fortified soy milk can contain calcium and vitamin B12, and thus, it can be used as an acceptable dairy substitute. Although soy milk has desirable isoflavones, which can be beneficial to heart health, it has a characteristic beany flavor and potential allergenicity (Messina, 2016). Conversely, other plant-based milks like almond and oat milk contain lower protein content and varying nutritional composition, which indicates the singular role of soy milk as a close dairy substitute.

PRODUCTION OF MILK Global and Indian Scenario:

Milk is one of the most consumed and produced dairy products in the world, playing a vital role in human dietary needs. India is the largest milk producer in the world, accounting for about 24% of world milk production, followed by the United States, China, Brazil, and Germany

(FAO, 2023). Milk production in India is mostly from buffaloes and cows, and milk from buffaloes accounts for about 50% of the total output. The prominent milk-producing states are Uttar Pradesh, Rajasthan, Madhya Pradesh, Gujarat, Punjab, Maharashtra, and Haryana (NDDB, 2023). The Indian dairy sector is highly decentralized with millions of small farmers producing milk through organized and unorganized channels. Prominent dairy cooperatives like Amul, Mother Dairy, and Nandini control milk processing and distribution. Projects like the National Dairy Plan (NDP) and Rashtriya Gokul Mission have been initiated to enhance the efficiency of milk production and productivity of livestock. In the world, the United States is the second-largest milk-producing nation, and the prominent milk-producing states are California, Wisconsin, Idaho, and New York. Germany, France, and the Netherlands are the leading milk-producing nations in the European region, and China has become a major producer, with focus on large-scale dairy farming and import to meet domestic demand. The rising demand for dairy products, coupled with advancements in genetic improvement, nutritional methods, and farm management practices, continues to drive growth in the world dairy industry (FAO, 2023; NDDB, 2023).

NUTRITIONAL VALUE OF SOY MILK (Modanwal, 2023)**:**

Physicochemical Properties	**Results**
pH	6.8 ± 0.02
Total Solids (g/100g soymilk)	84.1 ± 0.03
Moisture (g/100g soymilk)	85.9 ± 0.02
Ash (g/100g soymilk)	0.46 ± 0.02
Protein (g/100g soymilk)	6.24 ± 0.04
Fat (g/100g soymilk)	1.14 ± 0.02
Carbohydrate (g/100g soymilk)	2.66 ± 0.03

HEALTH BENEFITS OF COW MILK:

Milk is a nutritious liquid rich in essential vitamins and minerals essential for overall health. Milk is an all-round source of proteins, nutritional fats, and bioactive molecules that complement multifaceted physiological functions. The below depicts the definite merits of Cow milk:

1. **Excellent Source of Vital Nutrients:** Milk has a high concentration of a macronutrient mixture (carbohydrates, protein, and fats) and micronutrients such as calcium, vitamin D, vitamin B12, potassium, phosphorus, and riboflavin (Pereira, 2014). They are crucial for bone health, energy metabolism, and general well-being.
2. **Sustains Bone Health and Prevents Osteoporosis:** Milk is a good source of vitamin D and calcium, which are necessary for bone formation and bone health maintenance. Adequate calcium intake avoids osteoporosis and bone fractures, especially in old age and postmenopausal women (Heaney, 2009).
3. **Promotes Muscular Growth and Recovery:** Milk is a rich source of complete proteins (whey and casein) which are conducive to muscle repair and growth. Whey protein is rapidly absorbed and therefore suitable for post-exercise recovery, whereas casein is slowly absorbed and provides a time-released release of amino acids (Wilkinson et al., 2007).
4. **Boosts Immune System Efficiency:** The presence of immunoglobulins, lactoferrin, and bioactive peptides in milk is associated with antimicrobial and immune-enhancing activities. These substances are useful in combating infection and inflammation (Pereira, 2014).
5. **Improves Gastrointestinal Health:** Fermented milk products like kefir and yogurt have probiotics that enhance the balance of gut microbiota. Probiotics like Lactobacillus and Bifidobacterium enhance digestion, alleviate bloating, and enhance symptoms of irritable bowel syndrome (IBS) (Marco et al., 2017).
6. **Provides Enhanced Hydration Compared to Water:** Milk is an effective rehydration beverage due to its electrolyte balance and built-in sugars, which aid in fluid retention. Studies have determined that milk is superior to sports drinks in post-exercise hydration (Shirreffs et al., 2007).
7. **Weight Regulation Assistance:** Milk is very rich in dairy proteins and conjugated linoleic acid (CLA), whose intake has been linked with increased fat oxidation and a reduced risk of obesity. Studies have shown that increased intake of dairy will provide positive body composition when supplemented with a healthy diet (Zemel et al., 2005).
8. **Supports Cardiovascular Wellbeing and Reduces Hypertension:** Potassium in milk contributes importantly to blood pressure regulation by its capacity to balance the effect

of sodium. Bioactive peptides from milk proteins have also been shown to generate antihypertensive effects, thus reducing the risk of cardiovascular diseases (FitzGerald et al., 2004).

9. **Prevents the risk of Type 2 Diabetes:** Consumption of milk has been linked to enhanced insulin sensitivity. Milk proteins have been implicated in glucose metabolism, and they have been found to diminish the risk of Type 2 diabetes (Aune et al., 2013).
10. **May Reduce the Risk of Certain Cancers:** Several investigations indicate that the intake of milk, especially fermented dairy items, could potentially reduce the likelihood of colorectal cancer attributable to the inclusion of calcium, probiotics, and various other bioactive substances (Aune et al.,2015)

SOY MILK BENEFITS FOR FITNESS ENTHUSIASTS:

Soy milk is a vegetarian substitute for dairy that has become popular among bodybuilders at large because of its better-quality protein, essential amino acids, and other functional bioactive compounds. It is a good beverage for recovery during exercise, with multiple health benefits that improve muscle building, endurance, and sports performance in general.

1. **Best Protein for Muscle Building and Recovery:**

   Soy milk is considered one of the most superior plant-based sources of complete protein, as it contains all nine essential amino acids required for muscle repair and growth processes. One cup of soy milk has about 7–9 grams of protein, similar to cow's milk, and thus a wonderful alternative for vegans and lactose intolerance patients (Messina, 2016). Empirical research has shown that soy protein stimulates muscle protein synthesis (MPS), albeit slightly less effectively than whey protein due to its lower leucine content. However, the combination of soy with other protein sources, like pea or rice protein, can increase amino acid intake, allowing for more effective muscle development (Wilkinson et al., 2007).

2. **Rich in Branched-Chain Amino Acids (BCAAs) to build Endurance:**

   Soy milk contains branched-chain amino acids (BCAAs), such as leucine, isoleucine, and valine, which are needed for maintenance of muscle fatigue and enhanced exercise endurance. BCAAs are involved in maintenance of muscle tissue during intense exercise, thus leading to enhanced performance and faster recovery (Tang et al., 2009).

3. **Encourages Fat Loss and Lean Muscle Preservation:**

   For those who want to reduce adipose tissue while preserving lean muscle mass, adding soy milk to their diet may be beneficial. Isoflavones, certain plant compounds found in soy, are linked to better metabolic function and reduced body fat gain (Ho et al., 2020). Soy protein also plays an important role in preserving muscle mass, especially in the case of caloric restriction.

4. **Heart-Healthy Alternative to Dairy:**

   Unlike dairy milk, soy milk is low in saturated fats and cholesterol-free by nature, making it an excellent choice for heart-aware people. The FDA has recognized that the daily consumption of 25 grams of soy protein is beneficial in reducing low-density lipoprotein LDL (bad) cholesterol and lowering the risk of cardiovascular disease (FDA, 1999). Since most enthusiasts of fitness follow heart-healthy diets, soy milk is a healthy choice to maintain overall health.

5. **Maintains Bone Strength and Joint Health:**

   People who take an interest in fitness, especially those who engage in weight lifting or high-impact sports, need solid bones and joints to ensure they do not get injured. Soy milk is usually calcium and vitamin D fortified, both of which are essential to bone mineralization and protection against osteoporosis (Lanou, 2009). Additionally, the presence of isoflavones in soy has been shown to enhance bone density and suppress bone loss, hence being healthy for athletes as well as strength training individuals (Koh et al., 2005).

6. **Lactose-Free and Gut-Friendly:**

   Numerous sports players and healthy food consumers suffer from lactose intolerance, causing bloating, gas, and stomach upset. Soy milk is a lactose-free natural alternative, which is a good option for people looking to exclude dairy-induced gastrointestinal issues without compromising nutritional benefits (Vanga & Raghavan, 2018). Additionally, fermented soy foods, such as soy yogurt, potentially possess the ability to maintain gut health through promotion of favourable gut microbiota.

7. **Provides an Equilibrated Macronutrient Composition:**

   Soy milk provides a similarly balanced blend of healthy lipids, proteins, and carbohydrates, and is therefore a healthier choice to eat before or after exercise. Soy

milk's unsaturated healthy lipids assist hormonal balance and energy stores, while the naturally occurring carbohydrates provide a gradual release of energy when exercising. Soy milk producers also enrich their products with B vitamins, which are used for muscle function and energy metabolism (Messina, 2016).

Criteria	**Soy Milk (Better Choice)**	**Cow's Milk**
Source	Plant-based (soybeans)	Animal-based (cow's milk)
Protein Content	7–9g per cup (Complete protein)	8g per cup (Complete protein)
Branched-Chain Amino Acids (BCAAs)	Present but slightly lower leucine content than whey	Higher BCAA content (Better for muscle synthesis)
Muscle Recovery	Supports muscle synthesis, though slightly less effective than whey	Highly effective for muscle recovery (Better)
Fat Content	Low in saturated fat (Better)	Contains saturated fat (varies by fat percentage: whole, skim, or low-fat)
Lactose Content	Lactose-free (Better for digestion)	Contains lactose (may cause digestive discomfort)
Calcium & Vitamin D	Often fortified with calcium and vitamin D	Naturally rich in calcium and vitamin D (Better for bones)
Heart Health	Lowers LDL cholesterol, supports heart health (Better)	Contains dietary cholesterol but also provides heart-healthy nutrients
Bone Health	Supports bone density due to isoflavones	Stronger bone benefits due to high calcium, vitamin D, and phosphorus (Better)
Weight Management	Lower calories, helps in fat loss (Better)	Can aid in weight management depending on fat content
Gut Health	Dairy-free, easier to digest (Better)	Contains natural probiotics

		(especially in fermented dairy like yogurt)
Hormonal Effects	Contains isoflavones (plant compounds that mimic estrogen in small amounts, generally safe)	Naturally contains hormones from dairy cows
Best for	Vegans, lactose-intolerant individuals, those seeking a low-fat, plant-based protein (Better)	General population, athletes, and those needing high-protein dairy options
Sustainability	More environmentally friendly (Better)	Higher environmental impact (land and water use)

Conclusion

Soy milk is a plant-based, nutrient-dense dairy milk alternative with diverse health benefits, especially for athletes. As an overall protein source, soy milk is a good source of all nine essential amino acids and therefore effective as a muscle development, repair, and endurance agent. Its high branched-chain amino acids (BCAAs) content supports muscle protein synthesis, while its lower saturated fat and cholesterol-free compositions support cardiovascular well-being. Additionally, fortified soy milk supplies essential nutrients like calcium, vitamin D, and B vitamins, supporting bone health, energy metabolism, and well-being. For those looking for fat loss, muscle maintenance, or enhanced athletic performance, soy milk is an optimal pre- or post-exercise beverage, promoting lean muscle mass, sustained energy, and enhanced recovery. Its lactose-free quality also positions it as an optimal choice for those with dairy intolerance or gastrointestinal sensitivity. Isoflavones in soy milk also provide added metabolic and hormonal benefits, promoting long-term health outcomes. Employing soy milk as an addition to a sound fitness diet. A, either alone, or in conjunction with protein shakes, smoothies, or recovery meals can be a healthy and effective means of fulfilling dietary requirements. As a plant-based, eco-friendly, and versatile food, soy milk continues to be an excellent dietary ingredient for both athletes and health enthusiasts seeking peak performance and health.

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UNLOCKING DAIRY POTENTIAL: THE VITAL ROLE OF MINERAL MIXTURE IN DAIRY CATTLE NUTRITION

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Introduction

Dairy farming in India is undergoing a silent revolution. With rising demand for milk, small and marginal farmers are looking for cost-effective ways to enhance the productivity and health of their cattle. Minerals, although required in small quantities, are indispensable to every physiological function in dairy cattle. From bone formation and muscle contraction to milk production, reproduction, and immunity, these 'silent players' are behind every successful dairy operation. Despite their importance, many farmers still consider mineral mixtures optional. This article brings to light the crucial role mineral mixtures play in dairy cattle health and productivity and explains why they should be a **non-negotiable part** of every dairy farmer's feeding regimen.

2. What Are Mineral Mixtures?

A **mineral mixture** is a scientifically formulated combination of essential **macro-** and **micro-minerals** that meet the nutritional needs of dairy animals. It is usually a fine powder or pellet form, easily mixed with concentrate feed or green fodder.

Type	Minerals Included	Required Quantity
Macro-minerals	Calcium, Phosphorus, Magnesium, Sodium, Potassium, Sulphur	>100 mg/kg feed
Micro-minerals	Zinc, Copper, Iron, Iodine, Manganese, Cobalt, Selenium	<100 mg/kg feed

Each mineral has **a specific role** and a **specific requirement**. Imbalance either excess or deficiency can severely impact animal health.

3. Why Are Mineral Mixtures Necessary in Dairy Farming?

3.1. Depleted Soils and Forage

Over decades, continuous cropping and overgrazing have led to the **depletion of minerals in soil**, especially in rainfed and dryland regions. Consequently, the grasses and fodders grown in such soils lack critical minerals.

3.2. Poor Diet Diversity

Most small farmers rely on paddy straw, sorghum stover, and limited green fodder. These feed components are **low in bioavailable minerals**, especially calcium, phosphorus, and trace elements like zinc and selenium.

3.3. High-Yielding Animals Need More

Modern crossbred cows (HF, Jersey crosses) produce 10–20 litres of milk per day. For every litre of milk, a cow loses around **1.2 g of calcium and 1 g of phosphorus.** Without mineral supplementation, the animal draws these from her body leading to metabolic disorders and poor reproductive health

4. Functions of Major Minerals in Dairy Cattle

Mineral	Function	Deficiency Symptoms
Calcium	Bone strength, milk production, muscle contraction	Milk fever, lameness, reduced milk yield
Phosphorus	Energy metabolism, fertility, bone development	Pica, infertility, poor growth
Magnesium	Enzyme activation, nerve function	Grass tetany, muscle tremors
Sodium	Fluid balance, nerve function	Reduced appetite, pica
Zinc	Skin integrity, immunity, reproductive hormone function	Foot rot, poor healing, repeat breeding
Copper	Enzyme co-factors, pigmentation, immunity	Faded coat colour, infertility
Selenium	Antioxidant function, reproductive health	Retained placenta, white muscle disease in calves
Iodine	Thyroid hormone synthesis	Goitre, stillbirths, weak calves



5. Effects of Mineral Mixture Supplementation

Field trials and scientific studies have proven the wide-ranging benefits of regular mineral mixture feeding...

Field trials and scientific studies have proven the wide-ranging benefits of regular mineral mixture feeding.

5.1. Increase in Milk Yield

Minerals support the mammary glands metabolic activity. Supplementation has shown a **10–15% rise in milk yield**, especially in high-yielding animals.



5.2. Improved Fertility and Reproduction

Farmers often face issues like:

- Delayed estrus

- Silent heat
- Repeat breeding
- Anoestrus

Most of these can be linked to trace mineral deficiency. A well-balanced mineral mixture corrects these imbalances and restores reproductive efficiency.

5.3. Stronger Calves and Improved Calving Rate

Pregnant cows require additional calcium, phosphorus, and selenium. Supplementation helps in:

- Strong calf birth weight
- Reduction in stillbirths
- Decreased cases of retained placenta

5.4. Disease Resistance and Faster Recovery

Minerals like zinc, copper, and selenium boost **immunity**. Farmers report:

- Fewer mastitis cases
- Faster healing of wounds
- Improved response to deworming and vaccinations

6. Farmer Case Study: Sivagangai Success Story

In the **Koratti and Thattati villages of Sivagangai district**, under the guidance of **KVK-Kundrakudi,** 50 dairy farmers were provided with **TANUVAS Dairy Mineral Mixture** and trained in its usage.

Results after 3 months:

- **Average milk yield** increased by 0.5 to .75 litres per cow/day
- **Calving interval** shortened from 15 to 12 months
- 70% reduction in repeat breeding cases
- Improved **body condition score (BCS)** and hair coat
- Farmers reported that cows looked more energetic and active

7. How to Use Mineral Mixtures Effectively

7.1. Dosage and Method

Animal Category	Dosage per Day
Adult cow/buffalo	50–60 g
Pregnant cow	75 g
Heifer/calf	25–30 g

How to give: Mix with daily concentrate or sprinkle on moist green fodder. Ensure **consistent daily feeding.**

7.2. Don'ts

- Do not mix the entire month's quantity at once — it leads to wastage.
- Avoid exposing the mineral mixture to moisture — store in an airtight container.
- Do not replace mineral mixture with salt licks — they only provide sodium and chloride.

8. Addressing Common Misconceptions

Farmer Belief	Reality
"Our cows are grazing — they get all they need."	Most Indian pastures are **mineral-deficient**.
"It's too expensive."	Cost is only ₹1.5–₹2/day — but results in ₹15–₹30/day gain.
"Mineral mixture is only for sick animals."	It's for all animals **— prevention is better than cure.**
"My cow doesn't like the taste."	When mixed properly, most animals eat it without issue.

9. Conclusion: Investing in Invisible Inputs for Visible Gains

The importance of mineral mixtures can no longer be ignored in scientific dairy farming. These micronutrients, though invisible to the eye, fuel every system within a dairy cow metabolism, immunity, reproduction, and lactation.For marginal and progressive farmers alike, supplementing a **balanced mineral mixture daily** can mean the difference between average and optimal performance. It is a low-cost, high-benefit input that assures **sustainability, profitability, and animal welfare**.

Key Takeaways

✓Minerals are critical for milk production, reproduction, and immunity

✓Most traditional feeds are mineral-deficient

✓Mineral mixture supplementation is affordable and effective

✓Regular use improves yield, reduces disease, and boosts fertility

✓Use TANUVAS-recommended mixtures for your region

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WEED COMPOSTING – A TECHNOLOGICAL INNOVATION

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Introduction

WEED refers to a plant growing where not wanted, interfering with desired vegetation or causing other problems. It can also refer to the cannabis plant or its derivative products, often used as a slang term. Weed composting is the process of using unwanted weeds as a source of nutrient-rich compost for your garden. By properly managing a compost pile, including temperature, moisture, and aeration, you can transform weeds into a valuable soil amendment. This practice reduces the need for herbicides, helps improve soil fertility, and can minimize the spread of weed seeds



Technologies Used for Weed Composting:

Weed composting involves several methods to break down weeds and convert them into nutrient-rich compost.

These methods include:

Pit Composting: Weeds, along with other organic matter, are layered in a pit, often with cow dung and water to provide moisture and nutrients.

Aerobic Composting: Microorganisms break down organic matter, producing heat and humus, a stable organic end product.

Vermicomposting: Worms, such as red wigglers, are used to break down. This involves composting in the presence of ample oxygen product. Worms accelerate decomposition and produce a nutrient-rich compost.

Rotary Drum Composting: This method uses rotating drums to mix and aerate compost, accelerating the decomposition process.

Advantages and Disadvantages Of Weed Composting:

Advantages:

- Reduced Weed Growth
- Soil Improvement
- Potential Reduction in Chemical Herbicides
- Reduced Waste

Disadvantages:

- Persistent Weed Seeds
- Potential for Contamination
- Need for Proper Management
- Risk of Disease Transmission
- Potential for Smelly or Unattractive Compost

Weeds used for composting:

Chickweed, Dandelions, Clover, Plantain, Nettle, Crabgrass, Purslane, Pigweed, Lamb.

Ways to compost Weeds:

1. Pre-treating weeds:

Soaking-Soak weeds in water for 1 month to kill seeds and roots.

Drying-Leave weeds in the sun for 2-3 weeks until completely dry, which kills roots.

Black bag method, Place weeds in a sealed black bag in the sun for 10 days or more to kill roots, but seeds might still be viable without sustained heat.

2. Hot composting: Create a large compost pile, Mix greens and browns, Turning and aeration, Maintain moisture, High temperatures.

MATERIALS REQUIRED

Weed composting requires a balance of carbon-rich and nitrogen-rich materials, along with water and air, to facilitate decomposition.

Weeds themselves can be a source of green material, but its important to avoid seeds that may survive the composting process and re-introduce the weeds.

Other materials, like straw, leaves, and manure, can also be used as both green and brown materials, depending on their state and composition.

METHOD OF COMPOSTING FOR WEEDS:

- **Hot Composting**: This method uses heat to kill weed seeds and pathogens. A hot compost pile should reach temperatures between 130-160°F (54-71°C) for a few days to ensure effective seed destruction.
- **Cold Composting**: Cold composting is less effective at killing weed seeds, so its best to avoid putting weeds that have gone to seed into cold compost.
- **Bokashi Composting**: This method uses fermentation to break down organic matter, including weeds, more quickly than traditional composting.

MAINTANENCE OF WEED COMPOST

Maintaining a weed compost pile requires attention to balance, aeration, moisture, and temperature to ensure effective decomposition and weed seed destruction. Regularly turning the pile, maintaining a balance of green and brown materials, and ensuring proper moisture are key steps.

Key Maintenance Steps:

- **Balance:** Maintain a proper balance of green (nitrogen-rich) and brown (carbon-rich) materials. A good ratio is around 25:1 to 40:1 carbon to nitrogen.
- **Aeration:** Regularly turning the pile provides oxygen, essential for aerobicde composition.
- **Moisture:** Keep the pile moist, but not soggy, like a wrung-out sponge.
- **Temperature**: Hot composting can reach temperatures of 70°C (158°F), which can kill weed seeds and roots. Aim for temperatures of 130°F to 160°F.
- **Turning:** Turning the pile helps to distribute heat, aerate the material, and speed up decomposition.
- **Observation:** Monitor the pile for odor, moisture, and temperature. If the pile is too dry, add water. If it smells bad, add browns or aerate. If it's not heating up, add more greens and turn.

HARVESTING

Harvesting weed compost involves several steps.

First, the compost heap is checked for maturity, indicated by volume reduction, black colour, earthy odor, and reduced particle size. The heap is then disturbed, spread out, and cured for a day. Finally, the compost is sieved to ensure a uniform texture.

Detailed Harvesting Process:

1.Checking for Maturity: The compost is considered mature when it exhibits physical signs like reduced volume, a dark, earthy color, a pleasant earthy smell, and smaller particle sizes.

2. Disturbing and Curing: Once maturity is achieved, the compost heap is disturbed, and the material is spread out on a hard surface like a concrete floor to allow for further curing. This allows the material to dry and firm up.

3. Sieving: After curing, the compost is sieved through a 4mm sieve to ensure a uniform texture and remove any large, uncomposted materials.

4. Enrichment (Optional): For enhanced quality, the harvested compost can be enriched with beneficial microorganisms (like Azotobacter, Azospirillum, Pseudomonas, Phosphobacteria) and rock phosphate. This process, known as compost enrichment, increases the nutrient content and beneficial microorganism population

REQUIRED QUANTITY OF WEED COMPOST FOR FIELD APPLICATION:

The amount of weed compost needed for field application varies depending on the type of crop and soil conditions. Generally, a good starting point is 2.5 to 3.0 tons per hectare for basal dressing (application before planting), and 4 to 5 tons per hectare for vegetable crops. For specific crops like rice, sugarcane, and cotton, 1 to 1.5 tons per acre may be recommended.

Here a more detailed look at the benefits:

Every year we pull probably 200-300 pounds of weeds from our gardens. When we have composted this in a pile we ended up with lots of weeds germinating where we spread the compost. Is the problem that we aren't getting it hot enough? Or should we not throw weeds in the compost? Maybe have a separate rot pile for them. There are two issues I can think of - seeds and plants like bindweed and couch grass that can growing from bits of roots or stems. Seeds can sort of be avoided if you are careful but it is a pain to sort through the weeds and chuck them. If your pile gets hot enough it will cook the seeds but most piles are not big enough and don't get that hot - my pile of steaming horse manure will still produce loads of bits of grass and other

plants are there are loads of seeds in the pot. One thing you can do for other rooting plants that you have dug up is to drown them. Again it is a pain but a week or so in a bucket of water will most likely kill them and help them root down and then you can add to the pile. In my experience it is virtually impossible to avoid any plants growing - all you can d is to minimize the issue...

Additionally, weed compost can improve soil structure, water retention, and aeration, creating a more favorable environment for plant growth.

Nutrient Enrichment: Weed compost is a source of essential nutrients like nitrogen, phosphorus, and potassium, which are vital for plant growth and development. Incorporating compost into the soil provides plants with a natural and organic source of these nutrients, reducing the reliance on synthetic fertilizers.

Soil Health Improvement: Weed compost improves soil structure, increasing aeration and drainage, which promotes healthy root growth and nutrient uptake. It also enhances water retention, helping plants withstand drought conditions. Compost can also help to balance soil pH levels, making it more suitable for plant growth.

Weed Suppression: Composting can help to reduce the number of viable weed seeds in the compost, potentially leading to less weed competition with crops. Some studies have shown that compost extracts can be effective in managing weeds, according to BioCycle.

Reduced Reliance on Synthetic Inputs: By using weed compost, farmers can reduce their reliance on synthetic fertilizers and pesticides, promoting more sustainable and environmentally friendly agricultural practices.

Cost-Effective: Weed composting can be a cost-effective way to improve soil health and increase crop yields. It provides a way to utilize organic waste and reduce the need for expensive synthetic inputs. Weed compost, like other compost, works on soil by improving its physical properties, fertility, and overall health. It does this by adding organic matter, improving water retention and aeration, and providing essential nutrients for plant growth.

Improves Physical Properties: Compost acts as a soil conditioner, loosening heavy clay soils and improving their structure. It binds soil particles together, creating that are easier to work with and improve aeration, root penetration, and water infiltration.

Enhances Water Retention: Compost organic matter helps the soil hold more water, making it bettersuited for dry climates and helping plants access water during dry spells.

Increases Nutrient Availability: Compost provides a slow-release source of nutrients for plants, reducing the need for chemical fertilizers and minimizing nutrient runoff.

Boosts Soil Health: Compost supports a thriving ecosystem of beneficial microorganisms in the soil, which further improves soil health and fertility.

Suppresses Weeds: Applying compost as a mulch can help to smother existing weeds and prevent new ones from germinating, reducing the need for manual weeding.

Enhances Soil Aeration: By improving soil structure, compost promotes better aeration, ensuring that plant roots receive adequate oxygen. Compost helps to stabilize the soil and reduce its susceptibility to erosion by wind and water. Weed compost, like other compost, works on soil by improving its physical properties, fertility, and overall health. It does this by adding organic matter, improving water retention and aeration, and providing essential nutrients for plant growth.

For example:



Salvinia mosses



parthenium hysteroporus

1.Parthenium compost : Parthenium composting is a method of turning the invasive weed Parthenium (also known as Congress weed) into a valuable organic fertilizer. This process involves creating a compost pile or pit with layers of Parthenium biomass, soil, cow dung, and husk, ensuring moisture and semi-aerobic conditions. The decomposition process, which can take 4-5 months, kills seeds and converts the weed into a nutrient-rich compost that can be used as soil amendements.

Detailed Process:

1. Gather and Prepare Parthenium: Collect the Parthenium weed, ensuring its before flowering to prevent seed dispersal. Chop the weed into smaller pieces to aid decomposition.

2. Build the Compost Pit: Choose a shady, open location for the pit. Create layers of the Parthenium biomass, alternating with layers of soil, cow dung, and husk.

3. Moisture and Aeration: Maintain moisture by spraying water periodically. Ensure semi-aerobicconditions by turning the compost pile after a few weeks.

4. Decomposition: The decomposition process, driven by microorganisms, will naturally occur over several months. Temperature within the pile will rise, killing weed seeds.

5. Compost Quality: The resulting compost will be dark, fine-grained, and rich in nutrients, including nitrogen, phosphorus, and potassium, as well as micronutrients.

Benefits:

Weed Control: Composting reduces the spread of the invasive Parthenium weed by eliminating seeds.

Soil Improvement: The resulting compost enhances soil fertility, increasing nutrient content and improving soil structure.

Sustainable Agriculture: Parthenium composting is a sustainable way to utilize an unwanted weed,creating a valuable organic fertilizer and reducing reliance on synthetic fertilizers.

Biopesticidal Properties: Some studies suggest that Parthenium compost may have biopesticidalproperties, potentially reducing the need for chemical pesticides.

2. Salvinia mosses compost : Salvinia moss composting involves using microorganisms like bacteria and fungi to break down Salvinia (a floating fern) into a nutrient-rich compost. This process can help manage Salvinia infestations in water bodies and create a valuable soil amendments.

Key aspects of Salvinia moss composting:

- **Salvinia as a source:** Salvinia is a common aquatic weed that can cause problems in water bodies. It can be composted to address this issue and produce a useful product.
- **Microbial decomposition:** Microorganisms like bacteria and fungi break down the complex organic matter in Salvinia, converting it into simpler compounds.
- **Compost benefits:** The resulting compost can be used to improve soil fertility, increase water retention, and provide nutrients to plants.
- **Vermicomposting:** Salvinia can also be composted using earthworms, which can accelerate the process and create a high-quality vermicompost.
- **Potential for heavy metals:** Salvinia can absorb heavy metals from the water, which may be present in the compost. Care needs to be taken when applying compost derived from Salvinia, especially in areas where heavy metals are a concern.

Conclusion

Composting weeds is a beneficial practice that transforms undesirable plant matter into a valuable soil amendment. It offers a sustainable way to manage weed biomass, reduce waste, and improve soil health by enhancing fertility and structure. Properly composted weeds can also suppress weed growth in the garden by eliminating weed seeds and pathogens.

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A CRITIQUE OF ACADEMIC QUALITY: INTEGRATING PROCESSES. ASSURANCE. AND OUTCOMES

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Abstract

Strong educational standards in higher education rely on the interconnected elements of academic processes, quality assurance, and outcome assessment, forming the foundation for continuous improvement. The academic process centers on well-designed curricula, innovative teaching, engaging learning experiences, and effective assessments to foster intellectual growth and future ready skills. Quality assurance demonstrates a commitment to excellence through internal reviews, accreditation, and ongoing monitoring, ensuring programs meet standards and maintain credibility. Outcome assessment provides vital feedback by measuring if educational goals are achieved, using direct tools like standardized tests and indirect indicators such as graduate success. When combined, these elements create a dynamic, cyclical system driven by data-informed improvements. This system supports strategic planning and cultivates a culture of accountability and academic excellence. Deep integration of these components enables institutions to be effective, transparent, and adaptable, ensuring they do more than teach they truly empower students for the future.

Introduction

Academic quality is increasingly vital for schools, colleges, and universities worldwide. As technology advances, job markets evolve, and student expectations rise, institutions must

prepare learners for future challenges. Academic excellence now goes beyond reputation or regulatory compliance it requires delivering meaningful education that equips students for real-world success. A key driver is the growing demand for accountability and transparency. Parents, students, employers, and governments seek clear evidence that education is effective. In response, many institutions implement quality assurance systems and pursue accreditation to demonstrate high standards.

There is also a growing shift toward outcome-based education, where success is measured by what students learn and can apply after graduation. Teaching must be designed to help students achieve learning goals and become ready for professional and personal challenges. Achieving high academic quality requires alignment across three key areas: academic processes, quality assurance, and outcome assessment. Academic processes include curriculum design, teaching methods, faculty development, and student support. Quality assurance systems uphold and enhance standards, while outcome assessment evaluates whether students meet learning objectives and program goals.

Many institutions struggle to connect these elements effectively. Teaching often fails to respond to assessment results, and quality checks may focus more on compliance than meaningful improvement. Assessments can be viewed as formalities rather than tools to enhance learning. Improving education quality requires integrating academic processes, quality assurance, and assessment so they support one another. Clear standards, effective models, and global best practices can guide institutions in building responsive, student centered systems that promote continuous improvement and better serve students and society.

Rethinking Academic Quality in a Changing World

Academic quality refers to how effectively an educational institution helps students learn and achieve their goals by providing the right knowledge, skills, and experiences needed for future success. It encompasses all aspects of teaching and learning and is typically understood through three main components: inputs, processes, and outcomes. To improve academic quality, many institutions adopt models like Outcome Based Education (OBE), which aligns teaching and assessment with clearly defined student goals; Total Quality Management (TQM), emphasizing teamwork and data driven decisions; and Constructive Alignment, which ensures that course objectives, teaching, and assessment all work together to support learning.

- **Inputs** are the resources supporting learning, such as qualified teachers, well-designed courses, libraries, labs, and student services. Hiring experienced faculty and offering relevant programs indicate strong inputs.
- **Processes** involve how education is delivered and managed, including teaching methods, assessment styles, and leadership. Good processes ensure learning is clear, fair, and engaging, using techniques like group work and projects.
- **Outcomes** are the measurable results of learning, such as exam scores, graduation rates, job placements, and student satisfaction. Strong outcomes demonstrate education's real world value.

Academic Processes

1) **Curriculum Design and Review:** A well-planned curriculum defines what students learn, reflecting current knowledge and labor market needs. Regular reviews update content based on feedback from educators, students, and employers, ensuring ongoing relevance.
2) **Innovative Teaching Methods:** Moving beyond traditional lectures, education now focuses on student-centered approaches like discussions, case studies, and project based learning. Technology such as online quizzes and virtual labs enhances engagement and adaptability.
3) **Faculty Development and Qualifications:** Teachers' expertise and ongoing professional growth are vital. Institutions support continuous training and encourage faculty to stay current in their fields, fostering a culture of excellence.
4) **Student Support and Engagement:** Academic success requires support services like advising, tutoring, counseling, and career guidance. Encouraging student participation in internships, clubs, and decision-making builds leadership and collaboration skills.
5) **Institutional Leadership and Governance:** Effective leadership defines goals, allocates resources, and promotes transparency and accountability. Inclusive governance involving faculty and students helps maintain high academic standards and fosters innovation.

Quality Assurance in Education

Quality assurance (QA) involves systematic actions to uphold and enhance education standards, ensuring students receive meaningful and effective learning experiences. QA includes internal evaluations and external reviews to identify strengths and address weaknesses, fostering

continuous improvement. This process helps institutions maintain accountability, improve academic quality, and meet stakeholder expectations.

1. **Internal Quality Assurance (IQA)**

Internal quality assurance involves self-monitoring activities within an institution to maintain and enhance academic quality. This includes curriculum reviews, teaching evaluations, student feedback, and performance analysis. Departments regularly assess teaching methods, course content, and assessments to ensure alignment with academic goals and industry standards. Collecting student input helps improve classroom experiences. IQA also entails establishing internal policies, quality benchmarks, and dedicated quality units or committees. Staff receive training on quality standards and integrate them into everyday academic activities. By embedding quality practices internally, institutions foster continuous improvement without relying solely on external reviews.

2. **External Quality Assurance (EQA)**

External quality assurance is conducted by independent bodies such as accreditation agencies, government regulators, or professional organizations. These external evaluators assess whether institutions meet national or international academic standards. A common form of EQA is accreditation, which verifies that a program or institution meets established criteria related to courses, faculty qualifications, infrastructure, and student outcomes. Accreditation enhances credibility and reassures students, employers, and stakeholders of education quality. Other external assessments include audits, inspections, and performance reviews of governance, financial management, compliance, and strategic planning. These evaluations provide detailed feedback and recommendations for improvement.

Quality Assurance Models and Standards

Various frameworks guide institutions in developing quality assurance systems. For example, India's National Assessment and Accreditation Council (NAAC) evaluates higher education institutions on parameters such as teaching effectiveness, research output, infrastructure, and student support, promoting accountability and continuous enhancement. Internationally, ISO 21001 offers a management system for educational organizations, focusing on learner satisfaction and alignment of teaching with institutional goals. In Europe, the European Standards and Guidelines (ESG) provide a unified QA framework emphasizing transparency, stakeholder involvement, and systematic quality improvement. These models help

institutions benchmark performance, standardize practices, and pursue ongoing quality development.

Role of Data and Feedback

- ✓ Data and stakeholder feedback are crucial for quality assurance. Student surveys, focus groups, and course evaluations provide insights into learning experiences and satisfaction. Faculty, alumni, and employer feedback helps identify skills gaps and refine curricula.
- ✓ Quantitative data such as academic performance, retention, and graduation rates serve as indicators of institutional effectiveness, enabling informed decisions and timely interventions.
- ✓ Together, data and feedback form a comprehensive system supporting continuous educational improvement.

Outcome Assessment

Outcome assessment measures what students have learned, including knowledge, skills, and employability readiness. It evaluates teaching effectiveness and curriculum relevance. Assessment tools include exams, surveys, portfolios, performance tasks, and oral presentations, offering a well-rounded view of student learning and guiding improvements. Core assessment areas include knowledge to understand the subject content. The assessment encompasses both cognitive and practical skills, such as critical thinking and communication. Ultimately, employability depends on job-specific competencies and soft skills such as leadership and adaptability.

Aligning Assessment with Program Goals

Effective outcome assessment requires evaluation methods that closely align with a course's intended learning outcomes. For example, if a program aims to develop critical thinking or teamwork, assessments must specifically measure those skills. This alignment connects teaching, practice, and evaluation, helping students understand expectations and enabling educators to design meaningful, fair assessments that reflect course objectives. Clear alignment enhances transparency and enriches teaching and learning.

Using Results to Improve Teaching and Curriculum

Outcome assessment goes beyond grading it is a tool for continuous improvement. By analyzing results, institutions identify strengths and weaknesses in teaching and curriculum

design. If many students struggle with a topic, teaching methods can be adjusted, or additional support offered. Employer feedback may highlight skill gaps, prompting curriculum updates. These insights also inform faculty development and resource planning, creating a responsive educational environment centered on student success.

Integrating Quality, Processes, and Outcomes

A strong education system integrates academic processes, quality assurance, and outcome assessment. When curriculum planning, teaching, evaluation, and improvements align, institutions function more effectively. This holistic approach ensures coherence and responsiveness to student and societal needs.

Strategies for Aligning Curriculum, Teaching, and Quality Assurance

- Define clear learning outcomes.
- Align curriculum with these outcomes and review regularly.
- Use targeted teaching methods that foster intended skills.
- Match assessments to outcomes.
- Conduct regular internal reviews of teaching and performance.
- Gather and use feedback from all stakeholders.
- Leverage data for informed decision-making.
- Promote a collaborative quality culture involving faculty, students, and experts.

Best Practices from Institutions

- Regular curriculum workshops to align content with objectives.
- Grants supporting teaching innovation and technology use.
- Robust student feedback systems including surveys and committees.
- Transparency through published quality reports.
- Ongoing professional development for faculty.
- Employer engagement to keep curricula relevant.

Overcoming Barriers

Institutions can address integration challenges by raising staff awareness and training, securing leadership support, fostering collaboration, using user-friendly technology for data, and piloting initiatives before wide adoption.

Emerging Global Trends in Quality Assurance

Quality assurance is rapidly evolving, shaped by trends such as:

- **Artificial Intelligence (AI):** Enhances personalized learning and data-driven curriculum design.
- **Micro-Credentials:** Flexible, short certifications that demonstrate skills to employers.
- **International Rankings:** Drive institutions to improve research and teaching quality, influencing student choices and funding.

Bridging Gaps Between Research, Practice, and Future Challenges in Educational Quality

Despite strong research supporting the integration of teaching, assessment, and quality assurance, many institutions struggle to implement these connections effectively. Theoretical models often lack practical, scalable applications, pointing to the need for applied research that addresses real world challenges. Student involvement in quality assurance is limited, excluding key perspectives. Inclusivity also remains a major gap. Although equitable learning environments are widely advocated, many institutions have yet to adopt inclusive practices for diverse and special-needs students. Fragmented academic structures and misaligned curriculum, assessment, and quality metrics hinder coherent improvement.

While data collection is common, limited analytical capacity restricts its use for early issue detection and decision-making. Resource constraints such as insufficient funding, staff, time, and technology further obstruct the development of effective quality assurance systems. To advance, institutions must pursue integrated strategies, engage students in quality processes, and commit to inclusivity. Improved data use and systemic alignment are essential for building adaptive, high quality education systems.

Future Trends in Academic Quality

- ✓ **Digital Quality Assurance:** Increased use of digital platforms for automated self-assessments, online feedback, and data analytics will improve efficiency and responsiveness.
- ✓ **Student-Led Quality Assurance:** Students will take active roles in committees, co-designing evaluation tools, and peer reviews, promoting transparency and shared ownership.

- ✓ **Inclusive Quality Practices:** Future frameworks will emphasize equity and accessibility for diverse learners, including students with disabilities and underrepresented groups, enhancing fairness and opportunity.

Recommendations and Key Features for Enhancing Academic Quality

For Educators:

- ✓ Actively participate in quality assurance by giving constructive feedback and sharing insights.
- ✓ Adopt innovative, evidence-based teaching methods to engage students effectively.
- ✓ Utilize assessment data to continuously improve teaching strategies and learning outcomes.
- ✓ Commit to ongoing professional development focused on quality assurance principles and practices.

For Institutions:

- ✓ Integrate curriculum design, teaching, assessment, and quality monitoring for cohesive academic delivery.
- ✓ Encourage collaboration across departments to ensure alignment with learning goals and standards.
- ✓ Invest in digital tools and infrastructure to collect, analyze, and apply data efficiently.
- ✓ Involve students in quality assurance processes to gain valuable perspectives and increase transparency.
- ✓ Promote equitable and inclusive practices to meet the diverse needs of all learners.

For Policymakers:

- ✓ Provide sufficient funding and resources to support digital quality assurance systems and initiatives.
- ✓ Develop policies that emphasize student-centered and transparent quality assurance models.
- ✓ Support research that connects academic quality frameworks with practical implementation.
- ✓ Encourage inclusive participation of all stakeholders, ensuring fairness and accountability.

Conclusion

Curriculum design, teaching, quality assurance, and result assessment are all linked to achieving high-quality education. When they are aligned, they form a unified system that promotes effective learning and ongoing progress. This integration enables institutions to evaluate their strengths and shortcomings, make data-driven decisions, and create stakeholder trust. Challenges such as fragmented systems, restricted data utilization, and resource limits persist, but digital tools, student involvement, and an emphasis on diversity provide viable alternatives. Collaboration between educators, institutions, and policymakers is critical for developing adaptable, evidence based, student-centered systems that raise standards, assure accountability, and educate graduates to make significant contributions to society.

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ECOSYSTEM-BASED FISHERIES MANAGEMENT (EBFM): A HOLISTIC APPROACH TO SUSTAINABLE FISHERIES

Article ID: AG-VO5-I07-75

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Abstract

Ecosystem-Based Fisheries Management (EBFM) is a comprehensive approach to managing marine fisheries that incorporates ecological relationships, habitat conservation, and human dimensions. Unlike traditional single-species management, EBFM considers the complex interactions within marine ecosystems to ensure sustainable fish populations and healthy ocean environments. This article explores the principles of EBFM, including ecosystem dynamics, habitat protection, adaptive management, and stakeholder engagement. It also addresses the challenges faced during implementation and highlights examples of successful applications worldwide. EBFM is crucial for maintaining marine biodiversity, supporting coastal communities, and achieving long-term fishery sustainability.

Introduction

Fisheries provide essential nutrition, employment, and cultural value globally, but many marine stocks have been severely depleted due to overfishing and environmental degradation. Traditional fisheries management focuses largely on regulating the harvest of individual species, often neglecting the complex ecological and social systems they depend on. This narrow approach has led to unintended consequences such as ecosystem imbalance, habitat loss, and reduced resilience to environmental change.

Ecosystem-Based Fisheries Management (EBFM) represents a transformative shift toward holistic fisheries governance. It integrates ecological interactions, habitat conservation, and human factors to promote sustainable fisheries and ecosystem health. This article discusses the core components of EBFM, the challenges of implementation, and successful global

examples. Understanding and adopting EBFM principles is essential for preserving marine resources and supporting the communities that rely on them.

Understanding Ecosystem Dynamics and Species Interactions

Marine ecosystems consist of interconnected species linked through food webs, competition, and shared habitats. Fish population dynamics are influenced not only by fishing pressure but also by predator-prey relationships and environmental conditions. Overharvesting a key predator, for example, can cause prey populations to surge, destabilizing the ecosystem and affecting commercial fish stocks.

Traditional management often ignores these interactions, focusing solely on single-species stock assessments. EBFM explicitly incorporates ecosystem dynamics, allowing managers to anticipate indirect effects and maintain ecosystem balance. Protecting forage fish, vital prey for larger species, is one way EBFM supports broader ecosystem health.

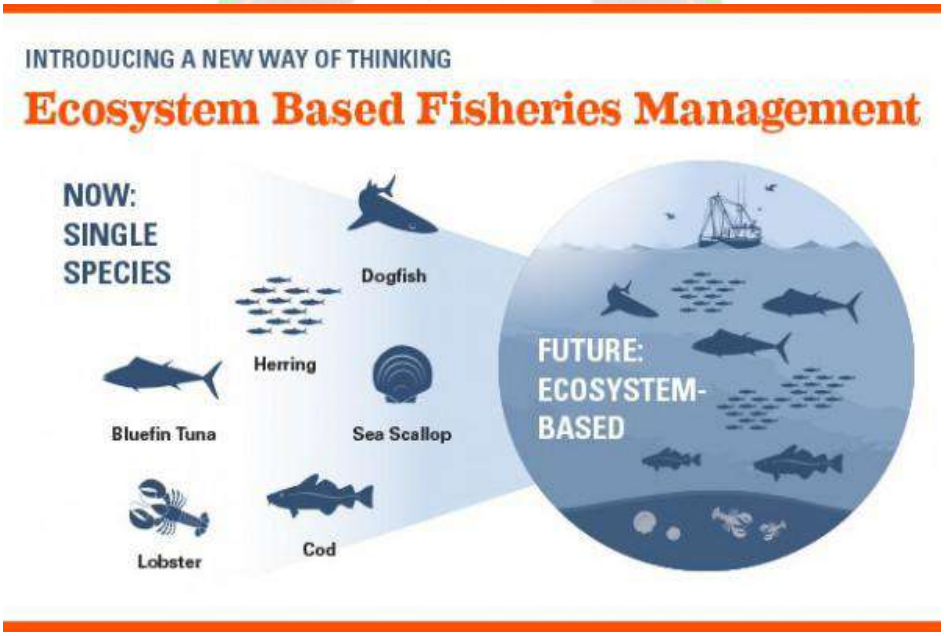


FIG 1: Understanding Ecosystem Dynamics and Species Interactions

Habitat Conservation: Protecting the Foundations of Fisheries

Critical habitats—coral reefs, mangroves, seagrass beds, and estuaries—serve as breeding, nursery, and feeding grounds for many fish species. Habitat degradation through destructive fishing practices, coastal development, or pollution diminishes fish productivity and biodiversity.

EBFM integrates habitat conservation within fisheries management. Establishing Marine Protected Areas (MPAs) and habitat restoration efforts preserve ecosystem functions that sustain fish populations. For example, mangrove restoration boosts juvenile fish abundance, enhancing coastal fisheries resilience.

Adaptive and Precautionary Management

Marine ecosystems are dynamic, influenced by natural variability and human activities such as climate change. EBFM employs a precautionary approach that errs on the side of conservation amid uncertainty. Adaptive management allows continual adjustment of policies based on monitoring ecosystem indicators like species abundance and habitat health.

For instance, shifting species distributions due to warming oceans require flexible management that can protect new critical habitats or modify quotas. This approach improves fisheries' resilience to environmental change.

Stakeholder Engagement and Collaborative Governance

Effective EBFM depends on the inclusion of diverse stakeholders—fishers, scientists, policymakers, indigenous groups, and communities. Participatory governance enhances transparency, compliance, and social equity. Incorporating local knowledge alongside scientific data results in culturally appropriate and practical management strategies.

Small-scale fisheries, which support millions worldwide, benefit especially from inclusive governance. Collaborative frameworks balance ecological goals with socio-economic needs, fostering sustainable livelihoods.

Challenges in Implementing EBFM

Despite its advantages, implementing EBFM faces several challenges, summarized below:

Challenges	Description
Data Gaps	Lack of comprehensive data on ecosystem processes, species interactions, and habitat conditions limits informed decision-making.
Institutional Fragmentation	Multiple agencies and jurisdictions managing different aspects of fisheries create coordination difficulties.
Conflicting Stakeholder Interests	Balancing ecological conservation with the economic and social needs of fishing communities often leads to conflicts.

Challenges	Description
Resource Limitations	Insufficient funding, scientific capacity, and enforcement resources hinder effective monitoring and management.
Climate Change Uncertainty	Rapid environmental changes increase uncertainty and complicate adaptive management efforts.

Conclusion

Ecosystem-Based Fisheries Management is essential for the sustainable future of the world's fisheries and marine ecosystems. By addressing the complex web of ecological interactions, habitat requirements, and human dimensions, EBFM fosters resilient and productive fisheries. While challenges such as data gaps, institutional barriers, and climate change exist, scientific advances and collaborative governance offer solutions. The widespread adoption of EBFM principles is critical for conserving marine biodiversity, securing food resources, and supporting the livelihoods of coastal communities globally.

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BIOREMEDIATION OF SOIL POLLUTION

Article ID: AG-VO5-I07-76

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Introduction

Soil pollution, primarily caused by the excessive use of pesticides, heavy metals, industrial wastes, and agricultural runoff, is a significant global environmental challenge. Traditional methods of soil remediation, such as chemical treatments and physical excavation, are costly, disruptive, and environmentally unsustainable. In contrast, bioremediation has emerged as a promising, ecofriendly, and cost-effective solution to restore contaminated soils. This paper provides a comprehensive overview of bioremediation techniques, their mechanisms, applications in agriculture, and their role in promoting sustainable agricultural practices. Additionally, it examines the potential benefits, challenges, and prospects of bioremediation in addressing soil pollution while ensuring long-term soil health and agricultural productivity.

SOURCES OF CONTAMINANTS

Pollutants are growing because of increased industrialization, contaminating the soil, water, and air. These pollutants are becoming more prevalent, endangering people, marine life, and the ecosystem. Contamination is caused by substances such as hydrocarbons, pesticides, herbicides, naturally occurring rock disintegration, and hazardous metals found in the environment. endangering people, marine life, and the ecosystem. Contamination is caused by substances such as hydrocarbons, pesticides, herbicides, naturally occurring rock disintegration, and hazardous metals found in the environment. Both is caused by substances such as hydrocarbons, pesticides, herbicides, naturally occurring rock disintegration, and hazardous metals found in the environment. Both anthropogenic and geogenic processes are the sources of contamination.

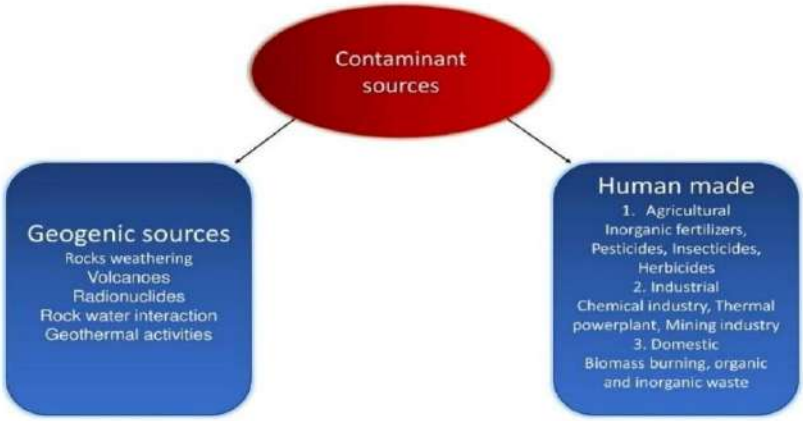


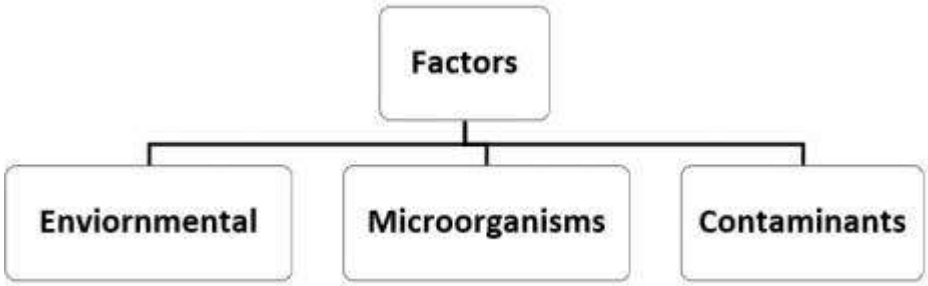
Fig. 1. Different sources of contaminants

Factors affecting bioremediation in soil

- Soil is the habitat of various type of microorganisms that receives and produce different kind of chemicals in diverse form and then act as a scavenger of hazardous substances.
- Factors like soil,type,moisture,pH,organic matter, and temperature affect the binding of individual and mixtures of a contaminant in soil.
- This, in turn, influences the effectiveness of bioremediation strategies Therefore, these factors are kept under the three categories.

Environmental factors

- Nutrients availability- Microorganisms are present in contaminated soil, though they are not in the desired numbers required for bioremediation of the site; therefore, their growth and activity must be stimulated.



- Bio stimulation usually involves the addition of nutrients to help indigenous microorganisms to grow their population.
- As microorganisms do require these nutrients as the basic building blocks

of life and also to secrete the necessary enzymes for the breakdown of the contaminants.

MODERN TECHNIQUES FOR IMPROVING BIOREMEDIATION

Nanotechnology:

Parameters	Condition required for microbial activity	Optimum value for degradation
Soil moisture	25-28% of water holding capacity	30-90%
Oxygen content	Aerobic, minimum air-filled pore space of 10%	10-40%
Nutrient content	N and p for microbial growth	C: N:P = 100:10:1
Temperature (°C)	15-45	20-30
Contaminants	Not too toxic	Hydrocarbon 5-10% dry weight of soil
Heavy metals	Total content 2000 ppm	700 ppm
Type of soil	Low clay or silt content	

Table 1: Optimum conditions required for bioremediation by microorganisms.

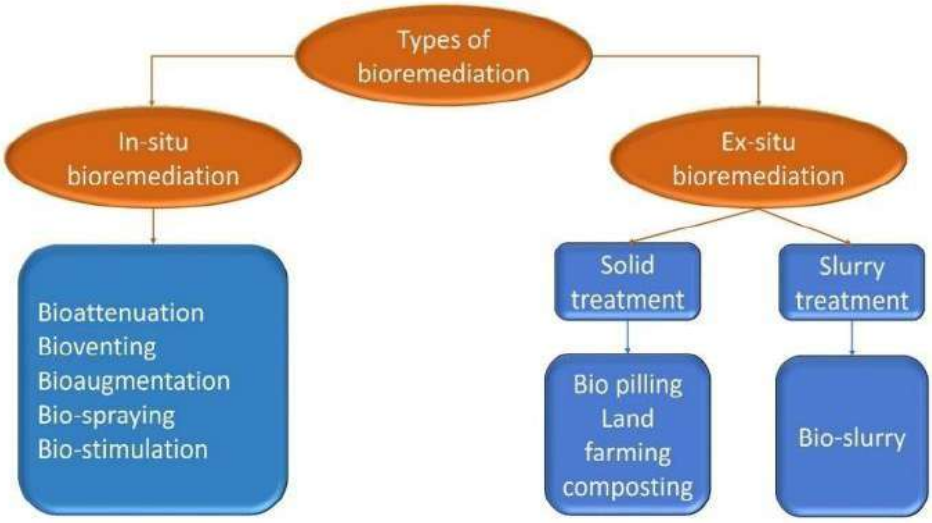


Fig. 2. Types of bioremediation

The process of producing nanoparticles, which is not expensive, involves the utilization of microorganisms. Environmentally friendly materials are used in nanotechnology. The heavy metals lead (Pb), arsenic (As), and cadmium (Cd), which are harmful to both individuals and the environment, are absorbed by these well-absorbent nanoparticles. By employing biosynthetic nanoparticles, nanotechnology offers an affordable method of eliminating pollutants from the air, water, and soil. It is an environmentally friendly method of removing pollutants from

contaminated materials. To clean up the contaminated materials, these nanoparticles which include carbon nanotubes, nano enzymes, and nano iron particles are utilized. These days, polluted substances are treated with a combination of metal nanoparticles, microbial biomolecules, and biogenic nanoparticles. Seventy percent of industrial pollutants end up in water bodies, harming aquatic life or posing health risks to humans due to their entry into the food chain. The primary source of pollution for aquatic bodies is the ever-increasing need for plastic. The size of this microplastic, which ranges from 5 to 1000 um, is found in large amounts in the stomachs of marine creatures.

ii) Electro bioremediation

- A relatively new technique called electro bioremediation uses electroactive microbes to control the oxidation and reduction process in conjunction with electrodes. These microorganisms can transfer or accept electrons.
- This technology uses electrokinetic processes such as
- electromigration, electroosmosis, electrophoresis, and electrochemical oxidation to remediate soil. These processes aid in the destruction of microorganisms since they alter their physical makeup. By exposing the microbial community to direct current, it aids in the breakdown of polycyclic aromatic hydrocarbons. The voltage of current is 2V per centimetres. This approach is multi-step, involving constant electric field, bio stimulation, and bioaugmentation. Increased activity of soil dwelling microorganisms is referred to as bio stimulation. The addition of microorganisms to the soil is known as bioaugmentation, and a constant electric field of 1 V per cent is applied
- This process causes the saline soil that is contaminated with petroleum hydrocarbons to become more ion-rich and capable of retaining more water. As time passes, the amount of soil ions surrounding the electrode rises

Limitations of bioremediation:

- While enabling toxins to biodegrade through bioremediation is a promising, cost-effective, and ecologically friendly approach, there are a number of challenges associated with it.
- Bioremediation may take a long time for complex contaminants with several links. The environment's pH, temperature, moisture content, and nutrient availability all affect efficiency of phytoremediation.

- Certain contaminants are resistant to biodegradation because they are complex or have persistent chemical bonds. Developing adaptable ways to deal with a variety of pollutants is crucial.
- Different contaminants need different microbial species, or bacteria that have undergone genetic modification, to break down.
- Finding the ideal combination might be challenging, especially in a new setting.
- Products that break down might still be hazardous after bioremediation. Ensuring the safety of these byproducts is crucial.

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DETERMINING THE SANITARY QUALITY OF WATER – BACTERIAL EVIDENCE OF POLLUTION

Article ID: AG-V05-I07-77

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Abstract

Bacterial indicators are one of the most reliable tools for detecting fecal contamination. Among these coliform bacteria serve as key markers for identifying fecal pollution in water. A high bacterial count normally indicates the presence of contaminants from domestic sewage, agricultural runoffs, or industrial discharge. This reflects the poor sanitary quality and also signals the possible presence of pathogenic microorganisms that can be of serious health problems that are waterborne. This detection thus calls for immediate action like water treatment, and regular monitoring to safeguard public health and ensure environment safety.

KEYWORDS

Jeopardizing, clogging, facultatively, fluorogenic, urbanization, intensification.

Introduction

Water plays a vital role in sustaining life and ecosystem making its conservation and equitable access a moral imperative. Its conservation and fair distribution is not just environmental concerns; they are the duties of every individual for sustainable living. Yet it can also be a medium for transmission of contagious diseases like cholera, typhoid, dysentery and hepatitis, if contaminated.

Continuous monitoring of water quality especially for pathogenic microorganisms from fecal matter is important and one of the primary concerns of recent times. One sip of unsafe water can trigger outbreaks, jeopardizing entire communities. As the world is facing rising water stress and pollution, ensuring clean and safe water for all is no longer optional but a

global emergency. Scientists and health officials rely on bacterial indicators for testing of sanitary water quality since it is cost effective and efficient.

BACTERIAL INDICATORS OF FECAL POLLUTION

Bacterial indicators are non-pathogenic microorganisms that indicate the presence of fecal matter in water and other samples. These indicators help in easy detection of pathogens and harmful microbes like **Salmonella**, **Giardia**, **Cryptosporidium**, and **enteric viruses**.

1. **Total Coliforms**:

These are groups of bacteria present in soil, water, intestines of warm-blooded animals and such other environments. These bacteria are not essentially harmful, but may indicate potential contamination and presence of other dangerous pathogens.

2. **Fecal Coliforms**

These are a subset of total coliforms that originated from the intestines of warm-blooded animals. They are facultatively anaerobic, rod-shaped and non-sporulating bacteria whose presence suggest that fecal matter has contaminated the water system, thereby increasing risk of disease transmission.

3. **Escherichia coli (E. coli):**

E. coli is a species of fecal coliform bacteria that is considered the most specific indicator of fecal contamination. While most E. coli is harmless, some E. coli strains like E. coli 0157:H7 can cause serious illness. High levels of E. coli suggest strong water contamination.

4. **Enterococci**:

These bacteria are found in the intestinal tracts of humans and animals and are also considered as the most reliable indicators of fecal contamination. They are more resistant to environmental stress and are often used in testing marine and recreational water quality.

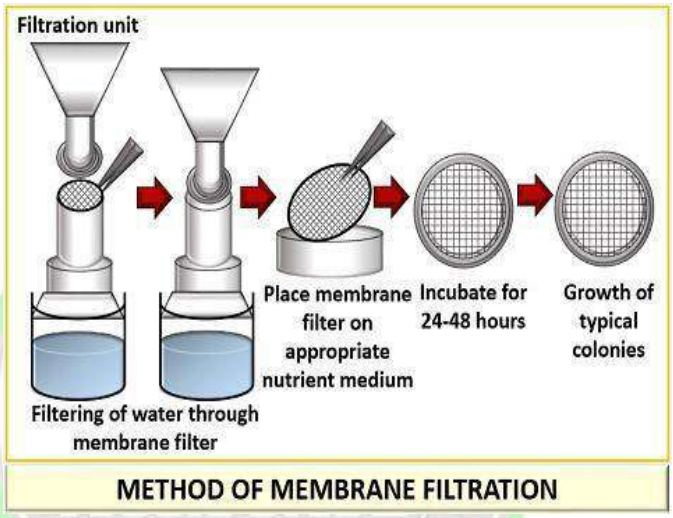
METHODS OF DETECTION

Several laboratory methods for detection and quantification of bacterial indicators in water are:

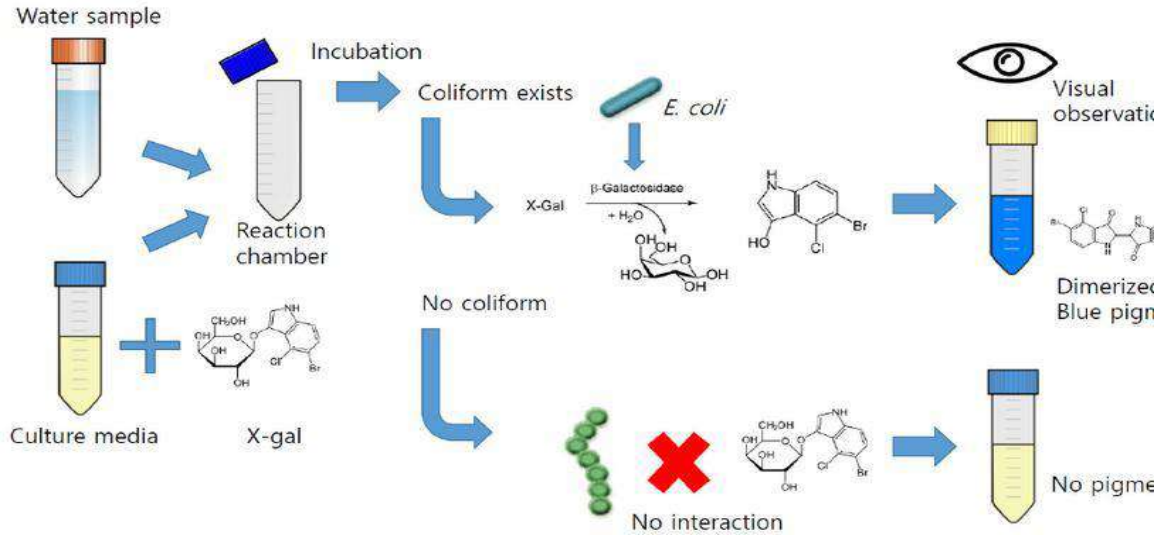
Multiple tube fermentation (MTF): Estimates the density of coliform bacteria in the sample by observing lactose fermentation in a series of inoculated tubes. It is a statistical approach as results are expressed as “Most Probable Number (MPN)”. In this method, water is added to a series of test tubes that are incubated at specific temperatures, say 35°C for total coliforms and 44.5°C for fecal coliforms. Bacterial fermentation of lactose produces acids and gases which is

taken as a positive result. MTF is suitable for turbid and sediment heavy water which can indicate bacteria even at very low concentration.

Membrane filtration: In this technique bacteria is separated from the sample using a porous membrane and cultured on a selective media to know its quantity. A known volume of water sample is passed through a sterile membrane filter placed on a nutrient agar plate, say; m- endo agar for coliforms. This method is faster and more quantitative than MTF and is used for large volumes of water testing. But it is not effective in case of highly turbid water as it may cause clogging.

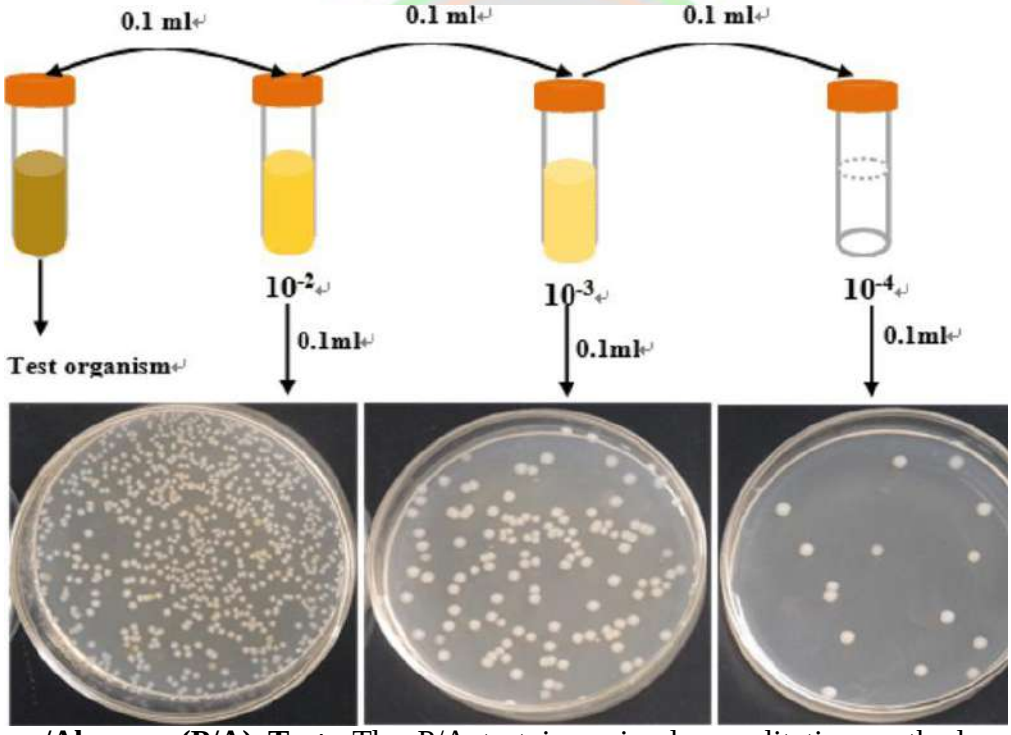


Enzyme substrate tests (e.g., Colilert, Enterolert): It is a rapid and efficient way that utilises specific enzymes produced by these bacteria to react with chromogenic and fluorogenic substances to bring about colour change or fluorescence..



Water sample is mixed with reagents that contain chromogenic or fluorogenic substances which can react with substrates of specific enzymes in coliforms (β-galactosidase) and E. Coli (β-glucuronidase). This results in a change in colour to yellow for chromogenic or fluorescence (under UV light) if bacteria is present. This method is highly sensitive and specific to coliforms and E. Coli. It is considerably costly too.

Colony count method: Also known as Standard Plate Count (SPC) or Viable Plate Count (VPC), is a technique used to estimate the number of live (viable) bacteria in water samples. This method involves plating a water sample directly on agar plates and allowing the bacteria to grow into visible colonies. Each colony represents a single bacterium or group of bacteria. Colony counting can provide both qualitative and quantitative data on bacterial contamination. It is widely used for water quality monitoring but can be labour-intensive and time-consuming.



Presence/Absence (P/A) Test: The P/A test is a simpler qualitative method used to detect specific bacteria like E. coli or enterococci. It involves growing the bacteria from a water sample in a single dose growth medium and observing. A colour change indicates presence and can be counted easily. It is widely used in rural areas for analysing the water quality for drinking purposes as it is simple, low cost and suitable for screening.

Polymerase chain reaction (PCR): PCR is a molecular method that detects bacterial DNA. This method can specifically identify harmful pathogens like *E. coli O157:H7* or *Salmonella*,

which are not always present in large numbers**.** DNA from water samples is isolated and amplified which is then studied using gel electrophoresis or using real-time PCR machines. This method requires skilled personnels, sophisticated equipment and is costlier than conventional methods but is highly accurate.

IMPLICATIONS OF BACTERIAL PRESENCE

After detection if the results suggest low or no trace, it indicates that water is safe for use and is of good sanitary quality. Whereas if the results have high count, the sample is fecal contaminated, contains pathogens and is unsafe for consumption or even contact. The presence of bacteria in water draws out serious public health, environmental and socio-economic consequences.

Conclusion

The detection of bacterial indicators in water is a stepping stone measure for public health and environmental safety. Unlike chemical pollutants that cause long term effects, microbial contamination has immediate and widespread health hazards. Using bacterial indicators, we can easily identify and address the contamination before it outbreaks into a pandemic. The high concentration of bacteria can reflect the breakdown of sanitary systems, improper waste disposal, contamination through runoffs, urbanization and industrial waste intensification. Monitoring bacterial contamination is sufficient for proper living and healthy survival of organisms in an ecosystem.

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RECENT INNOVATIONS IN AGRICULTURE

Article ID: AG-V05-I07-78

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Introduction

With the remarkable development of the world's population, as the United Nations Food and Agriculture Organization indicated, in 2050, there is a need to increase the consumption of food by 70 per cent, for horticultural land use and the exhaustion of natural resources, the need to increase the yield has become essential. To solve the above problems, IoT Solutions offer better product solutions, mainly aimed at helping farmers to shut down the inventory request hole by guaranteeing outstanding Returns, benefits and climate assurance. IoT provides various solutions that lay the foundation for helping farmers to improve productivity, profitability and environmental benefits.

IoT plays an important role, which includes specialized equipment, wireless connectivity, software and IT services. The use of Technology led to intelligent farming, because technological advances have Provided farmers with a better controlled ecosystem.

IoT Technology in Smart Agriculture

Data collected by intelligent agricultural sensors, a key component of this agricultural management approach, includes sensors, control systems, Robotics, self-supporting vehicles, automatic hardware, variable rate Technology, movement detectors, button cameras and wearable devices. Agricultural landowners can use various wireless IoT applications to collect information about the location, well-being, and health of their cattle so that they can identified and managed easily.

Role of IoT in Pest Monitoring

The technology now helps the farmers to monitor pests and act using wireless technology. Excessive use of pesticides on crops not only affect the human health but also the environment. Farmers are not aware of the exact application of pesticides and have harmful effects on other organisms including humans.

APPLICATIONS OF IOT IN AGRICULTURE

Drones

Drones are majorly used by the agriculture industry for monitoring and make tasks easy for farmers and thus enhance their productivity. They are used to monitor soil, spraying, watering and planting. Monitoring the soil helps farmers connect what is needed to help their crops grow better. Drones evaluate temperature, land slope, moisture, which gives them the right soil samples.



The benefits of IoT in farming have been shown using drones. They are built with different sensors and cameras used for taking images and surveying crops yield and fields.

Harvesting Robotics

The use of agri-business for crops resolves the labour shortages problems. These new machines can be operated 24/7 through the delicate selection process of fruits and vegetables. These machines use a combination of image processing and robotic weapons to determine fruit to control quality. Because of high operating costs for crops, focusing on agro-based early harvesting in fruit like apples.



Greenhouse Harvesting also applies to high-value crops such as tomatoes and strawberries with these **bots (software programmes designed for automating tasks)**. These bots can be used to properly determine the harvest stage in the greenhouse and harvest time.

Soil Quality

The soil quality analysis helps to determine the nutrient value and drying area of the fields, the capacity of drainage and the acidity of the soil, so that the water required for irrigation and the more profitable types of farming can be adjusted.

Predictive analytics

Data collected by IoT devices can be used to predict future **weather patterns, crop yields, and disease outbreaks,** enabling proactive management.

SENSORS USED FOR AGRICULTURE

- Agricultural Temperature Sensors
- Smart Cameras Use in Agriculture
- pH Sensors in Agriculture
- GPS Sensors
- Sensors for Resource Monitoring

Smart Cameras Use in Agriculture

The smart camera technology is used for a number of smart farming applications increasingly. Companies like John Deere's Blue River Technology have used intelligent camera technology to detect weeds and other plant locations to dispense herbicides and fertilizer automatically and accurately.

pH Sensors in Agriculture

The use of pH sensors provides basic criticism of soil supplement deficiencies or the presence of unwanted synthetic substances. It is user friendly and portable (can be carried easily to all places)



GPS Sensors

The GPS sensors are typically connected to car and cell correspondence companies. It has always been extremely important to farmers to monitor their herds. The Existing GPS monitoring of animals has enhanced the ability to screen animals with a basic catching press. Now, the sensors are being fitted in the harvester, and it detects the crop height, soil analysis for optimal harvesting and yield monitoring (no. of pods or grains etc.)



Conclusion

The intelligent agricultural sector is growing and expanding exponentially, with almost daily new horizons and technological solutions on the market. Capacity and

importance constantly increase in devices that collect sensor data, transmit information to farmers and help optimize Large-scale agricultural processes. IoT enabled agriculture to optimize the yield and to use the resource sustainably.

The uses of IoT in agriculture have brought a tremendous revolution in the field of agriculture. IoT in Agriculture therefore has a very promising future, and it is the driving force for efficiency, stability and scalability in this industry.

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MICROWAVE PLASMA ATOMIC EMISSION SPECTROMETRY (MP-AES) AND ITS APPLICATIONS

Article ID: AG-VO5-I07-79

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Abstract

The evolution of microwave plasma atomic emission spectrometry (MP-AES) was slower, and it did not achieve some commercial success until the introduction of Agilent's instrument in 2011. During the last nine years, the technique was utilized for the analyses of several metals from per cent to ng/ml levels in a variety of materials from drinking water to the most complex geological materials such as rocks and ores. The technique showed promising performance as a quantitative analytical tool and many groups published several papers dealing with the application of MP-AES in a variety of fields such as geological, environmental, food, health, energy, agricultural, pharmaceuticals, and waste electrical and electronic equipment regulation (WEEE)/restriction of hazardous substances (RoHS) compliance. Over this period, the instrument was also hyphenated to cold vapor (CV), hydride generation (HG), photochemical vapor generation (PVG), gas chromatography (GC) and high-pressure liquid chromatography (HPLC) techniques for the sensitive and accurate determination of elements like Hg, As and Se. In this review, an attempt is made to present an overview of the MP-AES technique along with a critical appraisal of its performance in different areas during the last 9 years (2012 – 2020). Future developments may focus on some of the drawbacks of the current systems such as source robustness and new spectrometer design for simultaneous wavelength measurements to compete with ICP-based techniques.

Introduction

Microwave plasma atomic emission spectrometry (MP-AES) was introduced at a time when two of the most popular analytical techniques, namely, inductively coupled plasma atomic

emission spectrometry (ICP-AES) and inductively coupled plasma mass spectrometry (ICP-MS) became sought-after techniques for the inorganic analysis of different materials. Atomic absorption spectrometry (AAS) technique was also equally popular at that time among analytical chemists. MP-AES with a self-sustained atmospheric pressure microwave plasma source using nitrogen gas, generated by nitrogen generator, offered a unique alternative to both AAS and ICP-AES techniques.

The technique showed much promise for routine analytical application with several advantages such as smaller footprint, multi-element capability, relatively inexpensive, low maintenance cost, good detection power and speed. The use of microwave plasma that runs on abundantly available nitrogen from a generator instead of bottles or liquid storing systems attracted the attention of several workers. Thus MP-AES has become a cost-effective analytical tool compared to ICP-AES or ICP-MS offering more possibilities than AAS. Though microwave plasma was used for elemental spectroscopy for the first time by Mavrodineanu and Hughes, the evolution of the MP-AES technique was slower, and it did not achieve some commercial success until the introduction of Agilent's instrument in 2011, which became an apparent interest to analytical chemists with the first research publication coming in 2012. In the last few years, interest in this technique has increased steadily, and its analytical capabilities are thus being evaluated in different areas. Since its commercialization, MP-AES techniques have been successfully applied in several areas such as geochemistry, mineral exploration, energy, environmental, agricultural, food, health and biotechnology and proved that the relatively new emission source is robust enough to handle different types of sample matrices.

How Microwave Plasma – Atomic Emission Spectroscopy works

Atomic spectroscopy describes a number of analytical techniques used to determine the Elemental composition of a sample by examining its Electromagnetic spectrum, or its mass spectrum. The techniques which identify an analyte element by Its electromagnetic spectrum include flame atomic Absorption spectroscopy (FAAS), inductively coupled

Plasma optical emission spectroscopy (ICP-OES) and Microwave plasma atomic emission spectroscopy (MP-AES). Those which identify an element by its Mass spectrum include inductively coupled plasma Mass spectrometry (ICP-MS), and triple quadrupole Inductively coupled plasma mass spectrometry (ICP-QQQ).

Atomic excitation

Microwave plasma atomic emission spectroscopy is an atomic emission technique. It uses the fact that once an atom of a specific element is excited, it emits Light in a characteristic pattern of wavelengths – an Emission spectrum, as it returns to the ground state. Sources for atomic emission include the microwave Plasma (MP) and the inductively coupled argon Plasma (ICP), both of which are high temperature Sources, and therefore excellent excitation sources. For atomic emission spectroscopy. The nitrogen fueled microwave plasma reaches temperatures Nearing 5,000 K. At these temperatures, atomic Emission is strong, producing excellent detection limits and linear dynamic range for most elements. Inside a MP-AES instrument, microwave energy from an industrial magnetron is used to form a Plasma from nitrogen that has been extracted from Compressed air by Agilent's Nitrogen Generator.

Using a magnetic field rather than an electric one for excitation generates a very robust plasma – Capable of handling a wide range of sample types. An optimized microwave waveguide creates concentrated electromagnetic fields at the torch. Then an axial magnetic field and a radial Electrical field focus and contain the microwave Energy to create a plasma.

MP-AES instrument





Safety

Removing the requirement for flammable gases Means no gas leaks and ordering and transporting of cylinders. Removing all of these risks makes your Laboratory a safer workplace.

Better performance than AA

An MP-AES has high sensitivity with detection Limits down to sub ppb levels and is faster than Conventional flame Atomic Absorption (AA) for A typical multi-element analysis

Fast & easy to use

The benefits of MP- AES Low cost of ownership

Gas supply is one of the highest costs associated with elemental analysis. Because the MP-AES runs on air, it vastly reduces the cost of ownership and eliminates the need for ongoing supply of flammable or expensive gases. There's no gas cylinders or Lamps to buy and no standby operating costs. When the MP- AES is off, no gas or power is used.

Agilent's MP-AES instruments feature easy-to-use, Application-specific software applets that Automatically load a pre-set method so you can start Analysis immediately without method development or Alignment, and with minimal training. The torch loader automatically aligns the torch and connects gases for fast start up and Reproducible performance.

Why switch from FAAS to MP-AES?

Reducing ongoing operating costs, increasing safety, improving analytical performance and simplifying Operation are some of the key challenges facing Current users of Flame Atomic Absorption Spectroscopy (FAAS). With the introduction of the Agilent Microwave Plasma-Atomic Emission Spectrometer (MP- AES), these challenges have been Overcome, making it the ideal instrument for Laboratories looking to transition away from FAAS to A more powerful, less expensive and safer technique. Additionally, with the extra performance of the MP-AES, the sample preparation process can also be Significantly simplified, saving time and money. The Agilent 4210 MP-AES features a waveguide Design and torch that can run samples with high total dissolved solids without Compromising detection limits.

Improved analytical performance

The plasma of the 4210 MP-AES operates at around 5000 K which results in improved detection limits When compared to FAAS. The improvements in the Detection limit means that it's possible to analyze Elements like phosphorus, which have very high Detection limits on FAAS.

Table 1 shows the instrument detection limits (IDL) On MP-AES and FAAS for elements in a rice flour Sample. The lower detection limits for P, Cu and Fe Allow the major, minor and trace elements to be Determined in one sample measurement.

Table 1. Comparison of typical instrument detection limits for the 4210 MP-AES and FAAS Element 4210 Ty

Element	4210 Typical IDL 10 sec read µg/L	FAAS Typical IDL µg/L
Ca	0.04	0.4
Mg	0.1	0.27
Na	0.1	0.26
K	0.6	0.76
P	66	26000
Fe	1.7	7.3
Pb	2.5	14
Cu	0.5	1.2
Mn	0.2	1.0

Simplifying sample preparation

A factor which greatly influences sample preparation Procedures on FAAS is the presence of interferences. Presence of compounds that cannot be broken down in the low temperature flame led to chemical Interference and elements like Na and K can suffer from ionization interference.

Conclusion

Agilent's 4210 MP-AES is the ideal instrument for customers looking to transition from Flame Atomic Absorption Spectroscopy (FAAS) to another technique. By using nitrogen as the source gas for the plasma, running costs are greatly reduced, and by removing the Requirement for hazardous nitrous oxide and acetylene Safety is greatly increased. Additionally, the higher Temperature nitrogen plasma atomization/ionization Source improves detection limits, linear range, and long-term stability, and allows the sample preparation Process to be greatly simplified.

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AGRICULTURAL SCHEMES AND DEVELOPMENT

Article ID: AG-V05-I07-80

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Abstract

Agriculture plays a pivotal role in ensuring food security, rural employment, and economic stability, especially in agrarian economies like India. Recognizing its importance, various governments and international agencies have introduced a wide range of agricultural schemes and development programs to support farmers, enhance productivity, and promote sustainable practices. Over the years, schemes like Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) for irrigation efficiency, Pradhan Mantri Fasal Bima Yojana (PMFBY) for crop insurance, Soil Health Card Scheme, Rashtriya Krishi Vikas Yojana (RKVY), and e-NAM (National Agricultural Market) have been implemented to address critical bottlenecks in the agriculture value chain. These initiatives focus on improving access to quality seeds, fertilizers, credit, markets, modern technology, and infrastructure. This paper explores the objectives, scope, and impact of key agricultural schemes, analysing their role in rural development, income enhancement, and environmental sustainability. It also highlights the need for better policy convergence, real-time data monitoring, farmer education, and climate resilience to meet the future demands of the sector.

Keywords: Agriculture development, Government schemes, Farmer welfare, Sustainable farming, Rural development.

INTRODUCTION

Agricultural schemes are important for farmers because agriculture sector provide

livelihoods to the people. Agriculture sector plays important role in the growth of the nation economy. To Support the agriculture sector and their growth government launch many schemes for the Farmers. These schemes are launched to enhance the income and to improve living standard of the farmers. Government of India is implementing numerous agricultural schemes for Welfare of farmers to improve their income and economic conditions. Name of the few Schemes are Soil Health Card scheme, Kisan Credit Card, Param paragat Krishi Vikas Yojana, Pradhan Mantri Krishi Sinchayee Yojana, National Agriculture Market, Pradhan Mantri Fasal Bima Yojana, National Horticulture Mission, Pradhan Mantri Kisan Samman Nidhi, Sub-Mission on Agriculture Mechanization, Pradhan Mantri kisan Sampada Yojana, Mission for Integrated Development of Horticulture. Pradhan Mantri Krishi Sinchai Yojana was launched in 2015, with the motto "More crop per drop." This scheme helps in use, creation, recycling, and potential Recycling of water under a single platform so that a comprehensive and complete assessment of the entire water cycle is taken into account and proper water planning for all sectors, like Household, agriculture, and industry (Kumar & Kumar, 2016). It improves efficiency, Sustainability, equity, and resilience at the farm level, particularly in rainfed, marginal, areas (Wani et al., 2016). Climate change and sustainable agriculture monitoring, modelling, and Networking was created with the goal of effectively disseminating climate change-related Information (Patel, 2016).

METHODOLOGY

The literature reviews collected from peer-reviewed articles published in various reputed Journals, research reports, books, magazines and internet sources etc.A final 47 scientific Articles reviewed after sorted and selected, based on suitability of topic from year 2005-2022.This study was confined to a reviews published study on awareness, knowledge and impact On farmers' income after adopting agricultural scheme, and constraint faced by farmers.

DISCUSSION

1.*Awareness and knowledge*

Sharma (2018) concluded that middle-aged farmer should participate along with young farmers. Awareness among the farmers and knowledge of the complete procedure should be clearly explained by the disseminating agencies, which may influence farmers positively to participate in e-NAM. Aggregation of produce by some agency or government can help farmers come to the Mandi for selling through e-NAM. Farmers should be encouraged to participate in e-

NAM by giving them a demonstration by setting the minimum price in Mandi. Singh & Hlophe (2017) observed sampled farmers had 88 per cent awareness about livestock insurance in Manzini Region, Swaziland. Kalamkar *et al*., (2019) found that lack of complete knowledge about e-NAM. The bank details and Adhaar card number required for registration with the system. They have worries about e-NAM and the following use of their income details for income tax purposes. Some Mandis organised meetings with farmers and traders and distribute printed leaflets for creating awareness. Thus, there is an urgent need for a strong and time-bound approach to educate and provide training to stakeholders on various aspects of the e-NAM concept. Bhadoriya *et al.*, (2022) found age was positively correlated with attitude of responded farmers towards Pradhan Mantri Fasal Bima Yojana in the study area.

2. *Impact on farmers income*

Vamsi (2019) revealed that the RKVY scheme had an optimistic impact on the income levels of sheep rearers, thus reducing inequality with regard to income levels as time evolved. Sheep Farming with technical intervention in the form of superior inputs could reduce income Inequality. Varshneyet al (2020) found that there was no selection partiality based on social and economically characteristics. Those who were relatively more dependent on agriculture and Those who and not able to access credit the scheme significantly helped them. Yadav (2019) Found that (43.34 per cent) of PMKSY (Pradhan Mantri Krishi Sinchayee Yojana) beneficiaries Were middle age (34.17 per cent) of the PMKSY beneficiaries were educated up to high School (43.33 per cent) of the PMKSY beneficiaries had medium land holding (37.50 per Cent) of the respondents had medium level of farming experience. Maximum beneficiaries (43.33 per cent) of Pradhan Mantri Krishi Sinchayee Yojanahad medium level of influence, (30 per cent) and (26.67 per cent) beneficiaries under higher and lower level of impact Respectively. Kavitha (2021) found that the beneficiary farmers compare than non- beneficiary Farmers are realising a 9.07 per cent higher gross return. Disbursement of funds should be timely, before the sowing season, to ensure the efficient use of the PM-Kisan scheme and to Realise maximum returns.

3.*Constraints*

Due to lack of awareness among farmers Soil Health Card scheme is not directly accessible To the farmers' community (Chaudhary, 2018). Kaur *et al*., (2020) revealed that the norms Recommended for they are not followed because lack of soil testing infrastructure as well Human resource. There is need of awareness campaign to reach Soil Health Card to maximum

Farmers. Goudapaa *et al.* (2018) concluded that inadequacy in implementing the scheme and Unawareness about the procedural to get benefit are the main hurdle in adopting scheme. Majority 46.25 per cent farmers fully utilized the credit while 17.50 per cent mis-utilized the Credit for the production purpose (Meghana, 2018).Kaur *et al*., (2021) concluded that almost 82 Per cent of the farmers felt the lack dissemination of information, 62 per cent farmers Reported complications in sale process, delay in online payments and difficult online payment Process were faced by 96.7 and 58 per cent of the farmers respectively. Moreover nearby 100 Per cent of the traders highlighted lack dissemination of information, 80 per cent of traders Reported complexity of sale process, 14.7 per cent reported the lack of trained personnel to Help them with e-NAM (85.3 per cent) of traders faced delay in online payments. In addition, about (89.3 per cent) of respondent traders faced difficulties getting licences for trading, and About (86.7 per cent) of Mandi officials agreed on the lack of adequate infrastructure at the Mandi 27 per cent said that farmers are afraid to get direct payments into their accounts.

Conclusion

It can be concluded that there is a need to create awareness among farmers to get maximum Benefits from the agricultural scheme of the government. Training and awareness through Extension services helps in achieving the schemes for the farmers. It is observed in most of The studies that few schemes are performing well and beneficiaries getting their benefits. The Agricultural schemes help in increase the yield of crops and the growth of agricultural Development in the nation. Many farmers have misconceptions about the schemes, and the Complex procedures of the schemes also discourage farmers for taking advantage of its Benefits.

Future scope

To understand the awareness level and constraints faced by farmers towards agricultural Schemes the study helps in understanding the constraints their impact on income and Awareness level. The further study helps in understanding the farmers' coverage under Schemes and beneficiary benefits performance of the schemes.

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EXPLORING THE VIBRANT WORLD OF VERSATILE ROSELLE CALYX

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Introduction

The roselle, scientifically known as *Hibiscus sabdariffa*, is an anthocyanin-rich plant and has a diverse array of applications. The plant, which belongs to a member of the Malvaceae family, has adapted to a diverse range of climates, thriving particularly in tropical and subtropical regions. Originating in Africa, the notable producers of this vibrant plant are countries such as Sudan, Mexico, India, Thailand, and China, each offering unique variants that contribute to a global tapestry of cultivation. The plant has other local names according to each region, such as Rozelle, Red sorrel, Jamaica sorrel, Guinea sorrel, Indian sorrel, Queensland jelly plant, Florida cranberry, etc. In India, it is popularly referred to as Patwa, Chukar, Lal-Mista, Lal-ambadi, Pulichakeerai, Polechi, etc and grown in the areas from Karnataka to Tripura, including Bihar, Maharashtra, Andhra Pradesh, West Bengal, Meghalaya and Odisha. According to studies, Andhra Pradesh has India's highest landforms for roselle production.

The national productivity of the crop is around 11q/ha. The flowering starts after 45 to 60 days of maturing. The yield that can be obtained for 14000 kg fresh calyces turns to 2000kg of dried calyces. Traditionally, Roselle has played significant roles in local cultures, from being a staple in traditional medicine and diets to its use in celebratory beverages and crafts. The vibrant, crimson-coloured calyx has captivated the attention of health enthusiasts, researchers and culinary experts.

This essay will delve into the fascinating world of the roselle, exploring its benefits, uses and potential applications.

Chemical Composition and Properties

These compounds, responsible for the rich pigment, also have antioxidant properties, which attribute health benefits to this plant. Roselle contains ascorbic acid, citric acid, and small amounts of iron, which have been recognised for their contributions to boosting immune function and promoting general well-being. The unique pigments offer visual appeal and are studied for their potential anti-inflammatory and lipid-lowering effects, thus underscoring Roselle's value beyond mere aesthetics.

The calyx of the roselle plant is renowned for its rich nutritional profile. It is a rich source of vitamins, minerals, and antioxidants, including vitamin C, riboflavin, niacin, and polyphenols. The roselle calyx has also garnered attention for its potential health benefits. Studies have suggested that the plant may possess anti-inflammatory, antioxidant, and hypoglycemic properties, making it a potential therapeutic agent for conditions such as diabetes, obesity, and certain types of cancer.

One of the primary uses of the roselle calyx is in the production of herbal teas and beverages. The calyx is commonly used to make a refreshing, ruby-red tea that is enjoyed worldwide for its tangy taste and potential health benefits. The tea is believed to have diuretic properties, which may help in the management of hypertension and other cardiovascular conditions.

Table. 1 Chemical composition of the dried roselle

S.NO	COMPOUND	COMPOSITION
1	Moisture (%) (dry Basis)	11.00
2	Crude Protein (%)	7.88
3	Crude fibre (%)	13.20
4	Ash (%)	10.60
5	Total Carbohydrates (%)	57.16
6	Crude fat (%)	0.16
7	Iron (mg/100g)	25.00
9	Ash (%)	10.60
10	Ascorbic acid (mg/100g)	11.00
11	Ca (%)	1.20
12	Mg (%)	1.57
13	P (%)	5.48

Colour extraction of roselle

The abundant amount of anthocyanin present in the roselle calyx contribute for antioxidant activities. The type of anthocyanins, such as delphinidin-3-O-sambubioside and cyanidin-3-O-sambubioside, are responsible for the vibrant pigmentation of the calyx. The more amount of colour can be extracted from dried calyces because the drying process concentrates the anthocyanins present in it. The colour extraction roselle can be done in both conventional and advanced methods. The conventional methods which include hot water assisted extraction, solvent extraction etc. It can be an alternative for the synthetic colourants. The advanced methods such as microwave assisted extraction, ultrasound assisted extraction, super critical fluid extraction, high pressure assisted extraction, enzyme assisted extraction etc. high yield from the roselle can be extracted from the advanced methods in that the ultrasound assisted extraction is considered as the common method and most viable method compared to other advanced methods. The disadvantages of the conventional methods are it includes longer time duration and involves manual works. The extraction of anthocyanin can be affected by several factors such as the temperature, extraction efficiency, amount of sample used, and natural characteristics.

Applications of roselle as a colourant in Various Industries

Roselle's applications span a broad range of industries, attesting to its versatility and demand. In the food and beverage sector, its tart yet refreshing flavor is a popular ingredient in teas, jams, and sauces globally. It lends vibrant color and flavor to a variety of dishes and drinks, making it a favourite among chefs and home cooks alike. The cosmetics and skincare industry harnesses Roselle's antioxidant-rich extract for its reputed anti-aging benefits, promoting skin health and enhancing beauty products' appeal. Additionally, the textile industry has a long history of utilizing Roselle for natural dyeing processes, yielding rich reds and pinks that are both environmentally friendly and aesthetically pleasing.

In addition to its use in beverages, the roselle calyx has found its way into various culinary applications. It can be used to add a unique flavour and vibrant colour to jams, jellies, sauces, and even baked goods. The calyx can also be dried and used as a natural food colouring agent, providing a natural alternative to synthetic dyes. The versatility of the roselle calyx extends beyond its culinary and medicinal uses. The plant's fibres can be used to produce textiles, paper, and even biodegradable packaging materials. Additionally, the plant's seeds can be pressed to extract an oil that has potential applications in the cosmetic and biofuel industries.

Some of the benefit of such colourant helps in preventing the lifestyle diseases such as hyperglycaemia, neurological and cancer problems, antioxidants, and anti-hypertension, among others.

Environmental and Economic Impact

The cultivation of Roselle presents both environmental sustainability and economic viability when conducted under optimal conditions. Sustainable farming practices, such as integrating Roselle in crop rotation and organic farming, help maintain soil health and reduce pesticide usage. Economically, Roselle contributes significantly to the incomes of smallholder farmers and local economies in producing regions. However, farmers face challenges, including market price fluctuations and climate change impacts that can affect yield stability. Addressing these challenges requires concerted efforts toward improved agricultural techniques and research to support the farmers who support this vibrant industry.

Conclusion

In conclusion, the roselle calyx, Hibiscus sabdariffa, has a wide range of applications and potential benefits. It is used in traditional herbal teas due to its promising therapeutic properties; its usage in industries such as food, cosmetic and drug industries has a high sustainable and non-toxic effect. The bio colourant is now booming in food industries. The researchers continue to captivate interest in roselle calyx in further beneficial products and expect to see even more innovative applications and discoveries in the years to come.

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USING REMOTE SENSING TO TRACK SOIL MOISTURE CHANGES OVER TIME

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Introduction

Soil moisture is a critical variable in the Earth's hydrological cycle, directly influencing plant growth, agricultural productivity, and environmental sustainability. Traditional methods of measuring soil moisture, such as in-situ sensors or gravimetric sampling, offer point-specific data but often fall short in capturing large-scale spatial variability. With the advancement of space technology, **remote sensing has emerged as a powerful and efficient tool to monitor soil moisture dynamics across vast areas**, over long time periods, and at multiple resolutions. This essay explores the principles, methods, applications, and future prospects of using remote sensing to track soil moisture changes over time.

Basics of Soil Moisture and Its Variability

Soil moisture refers to the amount of water contained in the soil pores. It is typically divided into two main types: **surface soil moisture** (top few centimeters) and **root-zone soil moisture** (top one meter or so). Several factors influence soil moisture content, including **climate, precipitation, soil texture, vegetation cover, and land use practices**. Its availability affects plant transpiration, microbial activity, and nutrient cycling. Since soil moisture can vary significantly across both space and time, especially in regions prone to droughts or floods, regular and broad monitoring becomes essential for informed environmental and agricultural decision-making.

Remote Sensing Techniques for Soil Moisture Estimation

Remote sensing technologies enable the estimation of soil moisture by capturing

electromagnetic signals reflected or emitted by the Earth's surface. The main techniques include:

- **Optical sensors**: These measure vegetation indices like NDVI (Normalized Difference Vegetation Index) to infer soil moisture indirectly. Drier soils generally result in stressed vegetation, which is captured in reduced NDVI values.
- **Microwave sensors**: These are the most effective for direct soil moisture estimation. They are divided into:
    - **Active sensors** (e.g., radar): Emit microwave signals and measure the backscatter from the soil surface.
    - **Passive sensors** (e.g., radiometers): Measure natural microwave emissions from the Earth. Passive systems are less affected by atmospheric conditions and vegetation.
- **Thermal infrared sensors**: Detect surface temperature, which can be inversely related to soil moisture. Drier soils heat up more quickly than moist soils.

These remote sensing techniques differ in resolution, accuracy, and cost, but collectively offer powerful tools for moisture monitoring.

Major Remote Sensing Satellites and Missions

Numerous satellite missions are dedicated to soil moisture monitoring. Some of the most important include:

- **SMAP (Soil Moisture Active Passive)**: Launched by NASA in 2015, SMAP combines both active and passive microwave sensing for global soil moisture mapping at 3–9 km resolution.
- **Sentinel-1**: Operated by the European Space Agency (ESA), it provides C-band synthetic aperture radar (SAR) data that are useful for high-resolution soil moisture retrieval.
- **MODIS and Landsat**: Though primarily optical, these satellites can be used in conjunction with vegetation indices to monitor soil moisture trends.

These missions provide **time-series data** that help track changes in soil moisture over days, months, and years, enabling the study of trends related to climate change, irrigation, or land management practices.

Data Integration and Interpretation

Raw satellite data often require processing and integration to derive meaningful insights.

Geographic Information Systems (GIS) play a key role in **layering remote sensing data with other geospatial datasets** such as elevation, land cover, and rainfall. Advanced **time-series analysis techniques** help track changes over time and identify patterns such as recurring droughts or seasonal variations.

Recently, **Artificial Intelligence (AI) and Machine Learning (ML)** algorithms have been used to improve soil moisture estimations by fusing data from different sources and correcting for anomalies like vegetation interference or sensor noise. These tools enhance the **accuracy, speed, and scalability** of soil moisture monitoring.

Applications of Soil Moisture Monitoring

Soil moisture data obtained through remote sensing has multiple applications:

- **Drought Monitoring and Forecasting**: Early detection of soil moisture deficits helps issue drought warnings and plan mitigation strategies.
- **Precision Agriculture**: Farmers can optimize irrigation schedules based on real-time moisture data, reducing water usage and increasing crop yield.
- **Flood Prediction**: High soil moisture levels can indicate reduced infiltration capacity, increasing the likelihood of surface runoff and floods.
- **Climate Change Studies**: Long-term monitoring helps assess how climate variability affects soil-water relationships and ecosystem health.

Remote sensing thus bridges the gap between data collection and actionable insights in both environmental and agricultural sectors.

Limitations and Challenges

Despite its benefits, remote sensing for soil moisture has several limitations:

- **Cloud cover** can interfere with optical sensors, especially in tropical regions.
- **Dense vegetation** masks soil signals, reducing the accuracy of microwave readings.
- **Spatial resolution** of passive microwave sensors is often coarse, limiting their use in small-scale studies.
- **Data processing** requires expertise and infrastructure, which may not be available in all regions.

Ongoing research is focused on overcoming these challenges by developing hybrid models and improving sensor technologies.

Future Prospects and Innovations

Future advancements are set to make soil moisture monitoring even more effective:

- **New satellite missions**, such as NASA's NISAR (upcoming), aim to provide high-resolution data globally.
- **IoT-based soil sensors** combined with remote sensing will enable real-time, ground-validated soil moisture data.
- Integration with **big data analytics** and **cloud computing** will make data processing more accessible and faster.

As technological barriers decrease, the use of remote sensing for soil moisture monitoring will become a mainstream tool for managing natural resources sustainably.

Conclusion

Tracking soil moisture changes over time is essential for sustainable agriculture, water resource management, and environmental conservation. Remote sensing provides a non-invasive, cost-effective, and large-scale method to monitor these changes with remarkable detail and accuracy. While challenges remain in terms of resolution and data interpretation, the continuous evolution of sensor technologies and data analytics holds great promise. With ongoing innovation and collaboration among scientists, policymakers, and farmers, remote sensing will play an increasingly critical role in shaping a climate-resilient future.

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UTILIZATION OF AGRICULTURAL DRONES IN VEGETABLE FARMING: A CONCISE REVIEW

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Abstract

Drones are unmanned aerial vehicle used for aerial data collection and spraying. The application of Agricultural drones (Spraying drones) in vegetable farming had a significant impact on farming practices. Spraying drones equipped with cameras and sensors can capture high-resolution images of crops, allowing farmers to identify potential issues such as pest infestations, disease outbreaks and nutrient deficiencies. Farmer's efficiency is increased in terms of using Agricultural drones. It includes cost-effectiveness, return on investment (ROI), labour savings (LS) and improvements in productivity. The use of AD, assisting farmers in tackling current challenges and ensuring future food production. AD enable farmers to monitor large areas of vegetable crops fields quickly, saving time and helps the farmers to achieve sustainable and financially sound operations compared to traditional methods. It potentially reducing labour costs and increasing the efficiency. It is cost-effective provides timely data leads to improved yields and reduced costs associated with over-fertilization and pesticide use. Research has shown that Agricultural drones can increase productivity up to 30 %. A study conducted in the United States indicated that Agricultural drones save farmers an 15 % in operational costs, primarily through more precise resource allocation. The review pointed out the significance of drone applications in vegetable crops and the immense potential of these tools in enhancing cultivation efficiency. Drone utilization enables the reduction of input quantities such as herbicides,

fertilizers, pesticides, and water but also the prevention of damages through early diagnosis of various stress types. These input savings can yield environmental benefits, positioning these technologies as potential solutions for the environmental sustainability of vegetable crops.

Keywords: Drones, efficiency, utilization, Vegetables

Introduction

In recent years, the introduction of drone technology has revolutionized various industries, including agriculture, engineering, military and expanding its applications. UAV's have evolved significantly since their inception originally designed for military applications, now widely used in commercial and recreational contexts [1]. According to the Federal Aviation Administration (FAA), as of 2023, there are over 1.7 million registered drones in the United States alone, enhances a growing interest and trust in drone technology. Moreover, the global drone market was valued at approximately $22 billion in 2021 and is projected is to $42 billion by 2026, signifying a compound annual growth rate (CAGR) of about 14.5 %. This growth can be attributed to a variety of factors, including advancements in battery life, the precision of sensors and the development of artificial intelligence capabilities. Drones are being deployed across multiple industries, facilitating processes and increasing efficiency. Some of the most prominent sectors utilizing drone technology include agriculture, construction, logistics and environmental monitoring [2].

Within the agricultural context, vegetables play a primary role; indeed, they are considered protective foods, providing essential nutrients to the human diet due to their richness in vitamins, fibres, minerals, and nutraceuticals [3]. Furthermore, regular consumption of fruits and vegetables contributes to the risk reduction of numerous diseases, including cardiovascular diseases and cancer [4]. Drones have become indispensable tools for modern cold crop farming operations. In vegetable cultivation, drones offer a range of applications like enhanced efficiency, productivity and sustainability. It helps in monitoring crop health, assessing frost damage, detection and management, precision agriculture, crop mapping and inventory, spraying and irrigation. Due to increase in global population and climate change, modern agriculture must enhance production efficiency (5). In this context, there is a growing adoption of advanced and intelligent techniques and technologies, such as artificial intelligence and unmanned aerial vehicles (UAVs) [6]. These vehicles enhance the cultivation processes, as they can perform monitoring and spraying missions, thus optimizing the efficiency of pesticide, fertilizer, and

water usage. They promptly identify stress induced by pests, diseases, nutritional and water deficiencies, while also facilitating the spraying procedure [7]. The applications of UAVs in agriculture are different and include nearly all agricultural productions. For example, applications in viticulture, olive cultivation, orchards, herbaceous crops, as well as vegetable cultivation, are well-established [8], [9], [10], [11], [12], [13].

The main objective of this review is to analyse how drones can be employed in precision agriculture concerning vegetable crops. This study aims to provide a comprehensive synthesis on the topic Utilization of agricultural drones in vegetable farming review of the last six years, focusing on the key objectives that can be achieved using drones in this field.

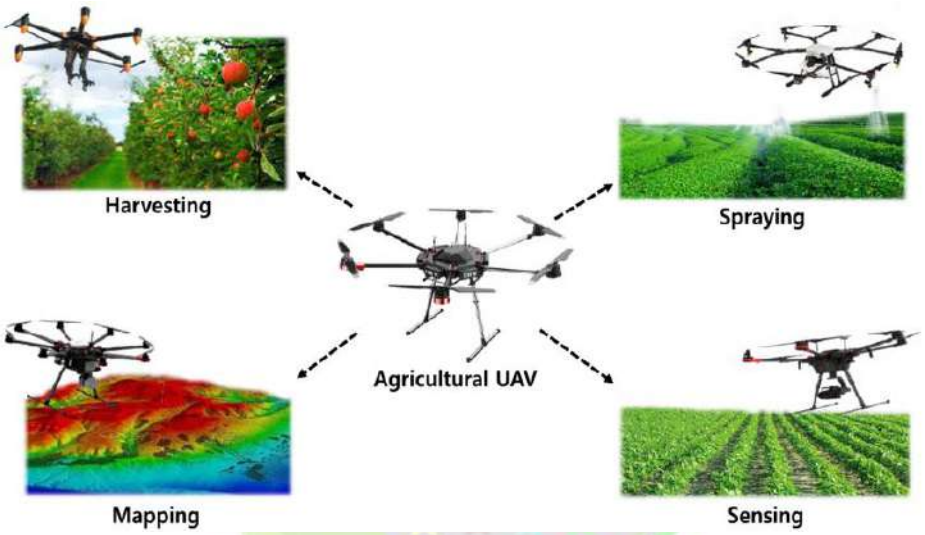


Fig.1 Vehicles enhancing cultivation processes [8,9,10,11,12,13]

Drones are unmanned aerial vehicle used for aerial data collection and spraying. A quad copter, is unique design of UAVs which has four rotors in their model. The lift of quadcopter is generated by these rotors and in four rotors, the two opposite rotors are turn in clockwise direction and the other two turn in counter clockwise direction. The quadcopter movement around the axis includes pitch (backward and forward), roll (left and right) and yaw (clockwise and counter clockwise).

Drones based sensors

Multispectral cameras which capture imagery across multiple wavelengths, can be used for the detection of differences in crop health and stress levels.

Thermal imagery sensors can detect temperature variations in crops, which can indicate abiotic and biotic stress (9).

LiDAR sensors can create detailed 3D maps of terrain and vegetation, providing valuable information of crop structure and canopy height.

GPS and navigation systems provides an essential information for precise positioning and navigation of drones, helps in accurate data collection and mapping.

Computers or onboard processors are used for real-time data processing and analysis and used for controlling drone flight paths. Before arrangement, farmers or operators plan flight paths and mission parameters using specialized software and this software accounts for factors like crop type, field size and desired data resolution.

Table 1. Drone based sensors used in vegetable crops (9-11)

S.No.	Sensor type	Function	Applications in vegetable cultivation	Benefits
1.	**Multispectral Sensor**	Captures images in multiple wavelengths (visible, near-infrared, red-edge, etc	Crop health monitoring (NDVI, NDRE analysis) Detecting nutrient deficiencies Monitoring plant stress	Early disease/stress detection Precision fertilization Improved yield prediction (9)
2.	**Thermal Sensor**	Measures temperature variations in crops	Detecting water stress and optimizing irrigation Identifying diseased plants Greenhouse temperature monitoring	Efficient water uses Early detection of plant diseases Controlled greenhouse environment (9)

3.	**RGB Camera (Optical Sensor)**	Captures high-resolution images of crops	Detecting pest infestations and disease outbreaks Assessing crop growth stages	Improved visual field monitoring Early pest/disease detection better decision-making for crop management (9, 10)
4.	**LiDAR (Light Detection and Ranging) Sensor**	Uses laser pulses to create 3D maps of fields	Measuring plant height and canopy density Creating topographic maps for precision irrigation Monitoring plant growth patterns	Accurate crop health monitoring Optimized irrigation planning better land management (10)
5.	**Hyperspectral Sensor**	Captures detailed spectral data for advanced crop analysis	Detecting early-stage plant diseases Identifying nutrient deficiencies Monitoring soil health	Higher precision in disease/nutrient deficiency detection Reduced crop losses Improved soil and plant management (11)
6.	**Gas Sensor**	Detect gases like nitrogen, CO_2 and ammonia	Monitoring greenhouse air quality Assessing soil respiration and microbial activity	Optimized greenhouse conditions Enhanced soil health analysis (11)

Data collected by Agricultural drones can inform precision irrigation strategies, deals with vegetable crops receive the optimal amount of water based on their specific needs (10).

Data analysis

The 132 papers that successfully passed the Identification, Screening, and Eligibility stages were exported to Excel. Data analysis was conducted using this software to consolidate the results from various studies on the topic of this review. The following data were extracted from each study: Title, Author, Year, analysed Species, Family, Study purpose, Sensor type(s), Sensor spectral range, Number of sensor bands, Post-processing techniques, Vegetation indices, and results obtained. The data extracted during this phase were analysed and evaluated. The data analysis revealed heterogeneity in the objectives obtained by using drones, and they were summarized into seven goals as described in section 34. Through data analysis, significant trends in this field of study have been identified. Fig. 2 graphically represents the distribution of the papers based on the crop families studied. In particular, 52 % of the papers focused on UAV applications within the Solanaceae family, underscoring the central role of crops like potatoes, tomatoes, peppers, and eggplants in both scientific research and agricultural production. The Brassicaceae family ranks second at 13 %, encompassing crops like cabbage, cauliflower,andradish.Subsequently,thereare Cucurbitaceae (9 %), Amaryllidaceae (8 %), Amaranthaceae (6 %), Rosaceae (5 %), Asteraceae (5 %), and Apiaceae (2 %).

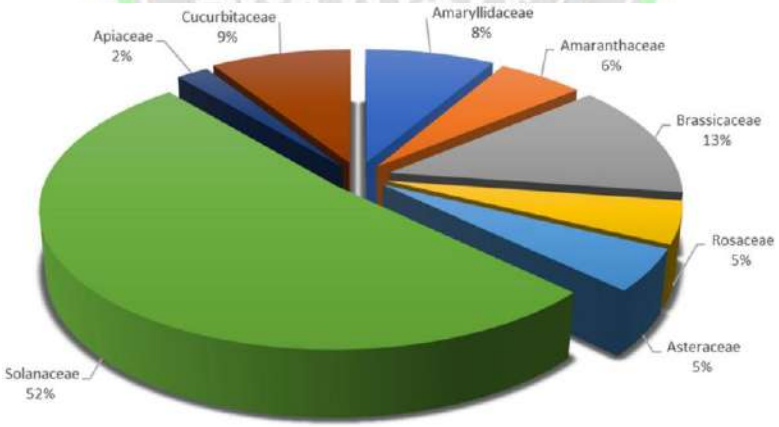


Fig. 2. Distribution of the papers based on the families of the species under study, along with their percentages.

Crop growth monitoring

A comprehensive list of crop growth monitoring in various vegetable crops (tomatoes, lettuce, cabbage, carrots, onions, Pepper, beans, etc) was shown (Table 2). Crop growth monitoring in vegetable crops is a critical aspect of modern agriculture that involves the

continuous observation and assessment of crop development to maximize yields, minimize losses and ensure sustainable farming practices (12). The widespread adoption of digital farming tools and software, such as farm management systems and IoT devices, which allow farmers to collect and analysed data on soil conditions, weather patterns and crop performance (13, 14). Crop growth monitoring in vegetable crops using spraying drones has revolutionized the agricultural industry in recent years. This technology has the potential to significantly improve crop yields, reduce input costs and minimize environmental impact. Initially, drones were used for aerial imaging and mapping of farmland, but their capabilities have since expanded to include real-time monitoring of crop growth and health (15). The development of low-cost, lightweight drones with advanced sensors has made this technology accessible to a wide range of farmers, including those growing vegetable crops. The impact of using Agricultural drones for crop growth monitoring in vegetable crops has been profound (16). Agricultural drones enable farmers to monitor their crops more frequently and accurately, allowing them to detect issues such as nutrient deficiencies, pest infestations and disease outbreaks early on. This early detection allows farmers to take timely action to mitigate these issues, leading to improved crop health and higher yields (17). Drones also offer the potential for more sustainable agriculture practices, as they can help optimize irrigation and fertilizer use based on real-time data. However, there are also challenges associated with the use of drones, including the high initial cost of the technology, regulatory hurdles and data management issues (18). Drones can provide farmers with detailed insights into crop growth patterns and variability within their fields. By conducting regular drone flights over their fields, farmers can create high-resolution maps of crop health, allowing them to identify areas of poor performance and implement targeted interventions (19). This level of precision agriculture can lead to significant improvements in yield, quality and profitability for vegetable farmers (20).

Crop growth monitoring in vegetable crops using drones has the potential to transform the way farmers manage their crops and make decisions about production. By providing real-time data on crop health, growth patterns and pest infestations, drones can help farmers improve their yields, reduce input costs and minimize environmental impact (21, 22,23,24).

Vegetable crop	Growth parameter monitored	Drone sensor used	Monitoring method	Key indicators	Actionable insights
Tomato	Plant Height, Leaf Area Index (LAI)	LiDAR, Multispectral	3D Canopy Mapping, NDVI	Canopy coverage, Leaf expansion	Adjust fertilizer & irrigation (12)
Chilli	Fruit Development	RGB, Hyperspectral	Image Analysis, Colour Segmentation	Fruit size, Color Changes	Harvest timing optimization (12,13)
Beetroot	Biomass Accumulation	Multispectral	NDVI, NDRE, LAI Analysis	Leaf area growth	Adjust fertilization & irrigation (14, 15)
Lettuce	Uniformity of Growth	RGB, Multispectral	Canopy Density Mapping	Uneven growth patches	Patches Precision nutrient application (16)
Pepper	Canopy Development	RGB, Multispectral	Vegetation Indices (NDVI, GNDVI) Hyperspectral	Canopy density,	Optimize spacing & nutrients (17) Predict
Bhendi					

Beans	Flowering & Fruit Set	RGB, Hyperspectral	Flower & Fruit Detection	Color changes	yield & manage pollination (18)
Carrot		Multispectral	Spectral Reflection Analysis	Number of flowers/fruits, Leaf Vigor, Growth rate	Optimize irrigation & nutrients (19)
Cabbage	Root Development Estimation	RGB, LiDAR	Canopy Volume Estimation		Adjust spacing & inputs (20)
	Foliage Density	RGB, Multispectral	Canopy Size & Texture Analysis	Leaf cover, Growth uniformity	Adjust water & nutrients (21-24)
	Head Formation			Head size, Leaf curling	

Table.2 Crop growth monitoring using drones in vegetable crops (12-24)

Crop Detection

When utilizing images acquired through UAV to extract information about plant morphology or health, they must undergo a processing procedure. One of the initial crucial steps in this process is Crop Detection [25]. Crop detection refers to crop identification, classification, segmentation, and/or mapping [26]. This process allows for isolating the crop of interest, referred to as Region Of Interest (ROI), within the images, while excluding everything that is not ROI, known as the background [27]. This background could simply be the soil, but it can also be

highly heterogeneous. For instance, [28] extracted the canopy of onions and garlic from a complex background consisting of plastic mulch, soil, and shadows under varying lighting conditions. Huang *et al.* [29] recognized the canopy of zucchinis intercropped with sunflowers. Regarding the methodologies employed to extract the crop from high-resolution images captured by drones, two primary categories can be distinguished: object-based methods, such as Object-Based Image Analysis (OBIA) or Geographic Object-Based Image Analysis (GEOBIA), and pixel-based methods, which primarily utilize Machine Learning and Deep Learning algorithms(Fig.3) [30].

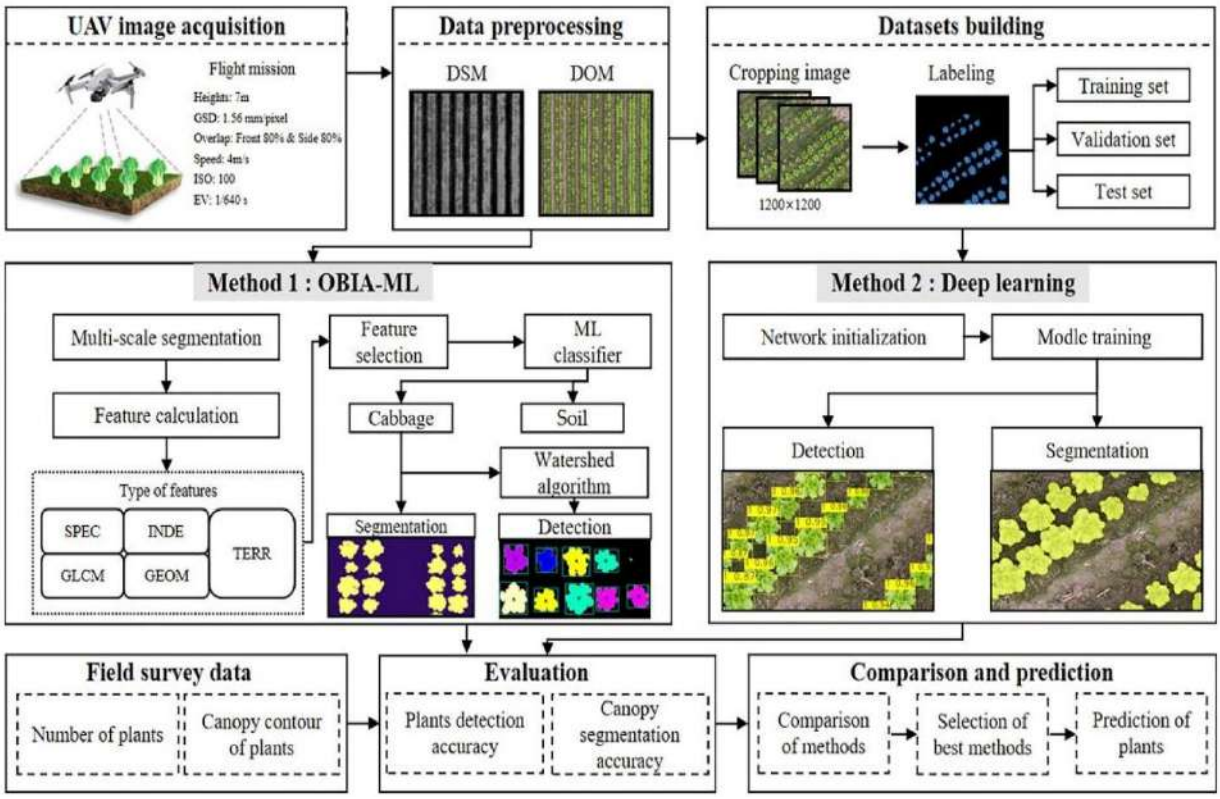


Fig.3 Machine Learning and Deep Learning algorithms (30)

Pest and disease monitoring

Pest and disease monitoring plays a vital role in crop production. Pest and disease monitoring in vegetable crops (tomatoes, chilli, brinjal, bell pepper, onion, etc) using drones (Table 5). The monitoring of pests and diseases in vegetable crops has been a longstanding practice in agriculture (31). Farmers have traditionally relied on visual inspections and scouting techniques to identify and manage pest and disease outbreaks. Technological advancements have revolutionized the way pests and diseases are monitored in vegetable crops (32, 33). Drones, are

unmanned aerial vehicles (UAVs), have become increasingly popular for agricultural applications due to their ability to capture high-resolution imagery and collect data in real-time (34). By utilizing drones, farmers can quickly and accurately identify areas of infestation or disease, allowing for targeted treatment and prevention measures. The use of drones for pest and disease monitoring in vegetable crops has had a significant impact on the efficiency and effectiveness of agricultural practices (35). Drones enable farmers to cover large areas of crops in a minimal time of period allowing for more frequent monitoring and earlier detection of pests and diseases (36).

The best results in classifying diseased plants were obtained using Linear Support Vector Classifier and Random Forest algorithms (Fig.4) both in terms of accuracy metrics and run time. Siebring *et al.* [37] employed a different approach in the detection of symptoms caused by Erwinia bacteria and PVYNTN virus in potatoes. They used high-resolution RGB images captured by drones for detecting morphological traits of plants. Subsequently, these traits were used as input in the Random Forest model, achieving a maximum F1 score of 0.75 and an average Matthews Correlation Coefficient (MCC) score of 0.47.

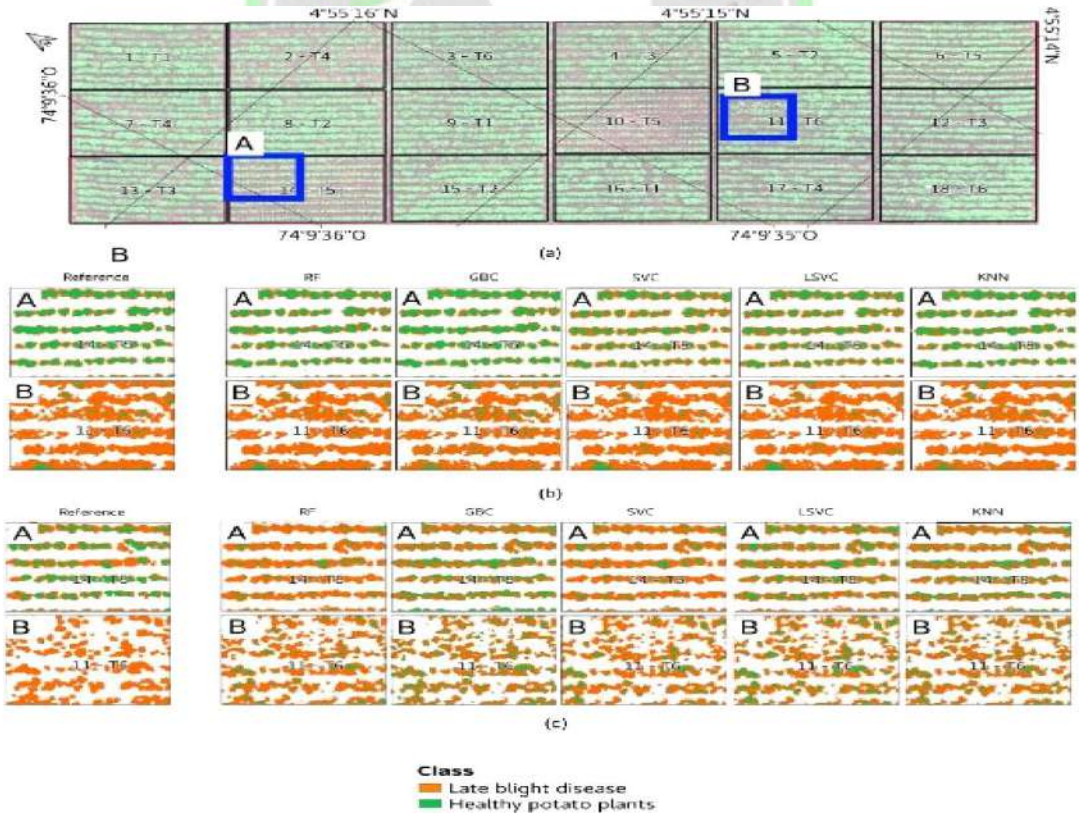


Fig. 4. Classification results for two datasets (A e B) in a study on potato field. (a) overview of the study area with regions of interest depicted in blue; (b) zoom to regions of interest for dataset A showing ground reference and the classification results; (c) zoom to regions of interest for dataset B showing ground reference and classification results (37).

Jindo *et al.* [38] applied drones equipped with multispectral and thermal sensors to detect and estimate the effect of varying densities of *Globodera Pallida and G. Rostochiensis* (Cyst Nematodes) on four potato cultivars. They calculated NDVI, NDRE, weighted difference vegetation index (WDVI), and Red-Edge chlorophyll index and observed regressions with nematode population density, finding good correlations except for one cultivar (avarna). Similar correlations were observed with thermal data.

Another important disease in potato cultivation is Verticillium wilt, which was the focus of the study by Lizarazo *et al.* [39]. These authors evaluated a machine learning algorithm that utilizes an ensemble of gradient boosting machines (GBMs) to differentiate between six levels of Verticillium wilt disease severity, achieving satisfactory results with F1 scores of 82 % for the training dataset and 84 % for the testing dataset.

Regarding tomato cultivation, different authors have identified several pathogens. Abdulridha *et al.* [40] detected bacterial spot and target spot both in the laboratory and in the field using hyperspectral imaging mounted on a drone,. By comparing various vegetation indices, they achieved the best results with the Photochemical Reflectance Index (PRI), $NDVI_{850}$, and chlorophyll index green (Chl_{green}). Additionally, the multilayer perceptron neural network (MLP) classification method achieved a 99 % accuracy for both Bacterial Spot (BS) and Target Spot (TS).

Lettuce was the subject of two studies. Cavalcanti *et al.* [41] estimated the effect of root-knot nematode incidence on lettuce growth by calculating vegetation indices and Vegetation Cover (VC) from RGB images. Carmo *et al.* [42] used multispectral images to detect lesions of Soft Rot (*Pectobacterium carotovorum*), employing Support Vector Machines (SVM) and Naive Bayes (NB) machine learning models.

In watermelon cultivation, Kalischuk *et al.* [43] proposed a drone-assisted scouting method with multispectral cameras for Gummy Stem Blight disease, achieving early disease detection in 20 % of cases. Abdulridha *et al.* [44] utilized hyperspectral images to identify and

classify Downy Mildew Severity Stages, achieving 62.3 % accuracy for low disease severity increasing to 91 % for higher severity.

In onion cultivation, Alberto *et al.* [45] created geopedological maps to detect anthracnose-twister disease-infected plants using multispectral images and SVM classification, yielding 85 % accuracy. McDonald *et al.* [46] explored the possibility of scouting Stemphylium Leaf Blight in onions using multispectral cameras, observing differences among disease severity levels without finding correlations with various indices.

In radish cultivation, Dang *et al.* [47,48] efficiently investigated Fusarium wilt. They segmented multispectral images captured by drones and employed a deep learning CNN algorithm for classifying diseased plants, achieving 96 % accuracy.

Spraying various inputs in vegetable crops

Spraying various inputs in vegetable crops (tomatoes, chilli, bhendi, bell pepper, onion, etc) using drones has revolutionized the agricultural industry by providing a more efficient and effective method of applying fertilizers, pesticides and herbicides (49). Drones, also known as unmanned aerial vehicles (UAVs), have become increasingly popular in recent years due to their ability to cover large areas in a short amount of time, reduce labour costs and minimize environmental impact. The impact of using drones for spraying various inputs in vegetable crops has been far-reaching. Farmers are now able to apply fertilizers, pesticides and herbicides more efficiently, leading to higher crop yields and reduced environmental contamination (50). The use of Agricultural drones has helped to reduce labour costs and improve overall farm productivity. Drones can cover large areas quickly and accurately, reducing the time and labour required for traditional spraying methods (51). One of the main concerns is the potential for pesticide drift, which can occur when chemicals are not applied properly or under unfavourable weather conditions (52). There are concerns about the cost of investing in drone technology and the lack of regulations governing their use in agriculture.

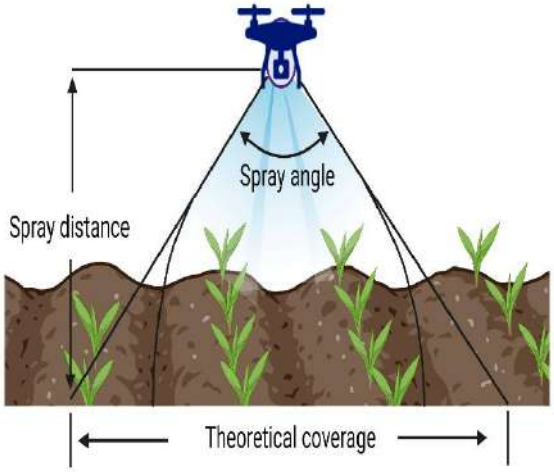
Application of drones in Cole crops

Drones can be useful in managing Cole crops like lettuce, spinach, cabbage, etc. It helps in monitoring crop health, apply fertilizers or pesticides precisely and helps in assisting planting seeds or seedlings in large fields. Their aerial view provides valuable data for optimizing irrigation and detecting early signs of diseases or nutrient deficiencies. Drones equipped with multispectral or thermal cameras can capture high-resolution images of cold crops. These images

can be processed to identify areas of stress, disease, or nutrient deficiencies. Early detection helps the farmers to take corrective action immediately and minimizing crop loss (53). Agricultural drones enable precise application of fertilizers, herbicides and pesticides shown in Fig. 5 and 6.



(5)



(6)

Fig. 5 Agricultural drone spraying in vegetable crops (cabbage)

Fig. 6 Spray coverage

Aerial spraying

The use of drones on vegetable crops for spraying operations has been investigated in recent studies by several authors. Drones equipped with a spraying system capable of performing targeted aerial treatments, leading to significant input savings, are used. The main components of aerial spraying drones include Brushless Direct Current Motors (BLDC), Electronic Speed Control (ESC), flight controller, GNSS system, accelerometer, gyroscope camera, transmitter, and receiver. For spraying, the two primary components are the pump and its controlling system



Advantages and Disadvantages of using drones in vegetable farming

- Increased Efficiency and Productivity
- Reduced Labor Costs
- Improved Resource Management
- Enhanced Data Collection and Analysis
- Accessibility to Remote Areas

Disadvantages: -

- High Initial Investment
- Regulatory Hurdles
- Technical Limitations
- Data Management Challenges
- Potential Safety Risks
- Privacy Concerns

Challenges of drone spraying in vegetable crops

- Drones can apply pesticides, fertilizers, herbicides, to specific areas of vegetable crops. It reduces the waste and minimizes the impact. Cole crops are sometimes difficult to access terrain due to uneven terrain or wet conditions. It is very difficult to spraying in a challenging environment. Drones can navigate these areas easily.
- Drones being an airborne, it can overcome the problem very easily. Using drone technology, time and labour efficiency can be reduced and yield can be increased. Drones spraying reduce the risk of exposure to harmful chemicals for farm workers. It promotes the safer working conditions in cold crop farming.
- Drones have limited battery life, which are exacerbated in cold weather conditions. It leads to shortening of flight time and limiting the area covered during each operation. Usage of drones are highly restricted in Cole crops area due to climatic factors. It limits the drone utility. It is costly and expensive. Operating a drone requires a skill and training experts.
- The materials used in the drone's construction contract in cold weather, affects the drone's structural integrity and flight dynamics. Sensors and electronic components are affected by cold weather leads to inaccurate readings or malfunctions.

- Drones are used for covering large areas and not a complete replacement of human power. Drones are used for Precision agriculture and deployed in Pesticides for dispersing and reduced human intervention in Agriculture works instead man-made spray techniques in cereals and pulse crops. According to the temperature and crops height it will differs a lot.
- Increasing the altitude the dispersion of pesticides and the liquid we are using it will spread in large area will make a drift and possible chance of dispersion of liquid in buffer areas and outside the fields and will not disperse up to the ground when it comes to crops like tomato, brinjal, etc. The drone will not able to cover up to the last leaf or the fruits in the crops while increasing the altitudes increasing in payload and increasing the dispersing liquids or pesticides will be the solution for the complete disease.
- When it comes to crops like cabbage, carrot, cauliflower, cabbage, radish, beetroot, etc are growing high altitude requires a nominal or minimum temperature because the due drops on the crops or in the leaves in the vegetables are the smaller bad conditions for drone.
- The amount of dispersing liquid will vary from the man-made spraying and drone. The maximum SOP was restricted for all crops in the agriculture sector up to 20 litres per hectare the amount of discharge will not give a major impact in diseased crops.

The Namo Drone Didi scheme

- In the heart of rural India, a quiet revolution is taking flight — quite literally. The Drone Didi scheme, launched by Prime Minister Narendra Modi, is transforming the lives of women in villages by equipping them with cutting-edge skills in drone technology.



- At the forefront of this movement is Sakshi Pandey from the Sagar district of Madhya Pradesh, whose journey from traditional employment to technological empowerment is inspiring hundreds across the country.
- The Drone Didi scheme empowers rural women with drone skills. Sakshi Pandey from Madhya Pradesh has trained over 200 women and now earns Rs 25,000 a month.
- This is more than a job; it's a path to self-reliance and dignity," she says.
- The government continues to support this initiative by offering regular training sessions and financial subsidies to women interested in becoming drone operators. The Namo Drone Didi scheme is not merely a technological programme; it is a movement that is uplifting rural women, strengthening communities, and ushering in a new era of agricultural advancement.

Other relevant schemes:

- **KISAN DRONE SCHEME – AKASHDOOT:** This scheme by Bank of India offers loans to farmers for purchasing drones and related equipment for various agricultural purposes.
- **Union Kisan Pushpak Loan Scheme:** Union Bank offers loans to farmers for purchasing drones and related equipment, with a repayment period typically ranging from 3 to 7 years.
- **Canara Drones:** Canara Bank provides loans to farmers for purchasing drones and related equipment for agricultural purposes.





Conclusion

The review points out the significance of drone utilization in vegetable crops and the immense potential of these tools in enhancing cultivation efficiency. Drone applications in vegetable crops in the literature are increasing more and more, with the number of dedicated papers on this subject growing year by year. The scientific knowledge in this field, combined with the array of information that drones can provide, will be employed by agronomists, agrotechnicians, and specialized consultants in precision agriculture. These professionals will be capable of offering farmers increasingly informed and precise operational guidance, thereby contributing to the optimization of agricultural management practices and yielding economic and environmental benefits. From an economic standpoint, drones can provide a dual advantage. Their utilization enables the reduction of input quantities such as herbicides, fertilizers, pesticides, and water but also the prevention of damages through early diagnosis of various stress types. Additionally, input savings can yield environmental benefits, positioning these technologies as potential solutions for the environmental sustainability of vegetable crops.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

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MANAGEMENT OF AGROCHEMICALS FOR SUSTAINABLE AGRICULTURE

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Introduction

Agrochemicals are broad class of chemicals or biological substances. It includes all the pesticides (i.e. insecticides, herbicides, fungicides, etc.) and fertilizers which are essential for modern agriculture. The play an important role in boosting crop yields and enhancing food production to meet the demands of a growing global population. These chemicals help protect crops from pests, diseases, and weeds, while also providing essential nutrients to the soil, leading to healthier and more productive plants.



Source: researchgate.net

The problem arises when agrochemicals are used in improper way or by excess application leading to various environmental and health problems, including water and soil

pollution, pesticide drift, and potential risks to human health. Runoff from agricultural fields can contaminate water sources with pesticides and excess nutrients, leading to algal blooms (eutrophication) and harming aquatic life. Pesticide drift (the chemicals are suspended in the air) can affect non-target organisms and contaminate neighbouring areas. Additionally, prolonged exposure to agrochemicals can pose risks to the health of farmers and rural communities.

Therefore, effective management of agrochemicals is crucial for sustainable agriculture. This involves adopting a range of strategies to minimize negative impacts while maximizing the benefits of these inputs.

Strategies to overcome agricultural pollution

i) Ethics

It includes the responsible use, proper storage, disposal, and adherence to regulations. The key rule is minimizing environmental impact and promoting sustainable practices. The good agricultural practices are to follow the ethical consideration, and it is the responsibility of all the citizens to act accordingly while using agrochemicals.

The Food and Agricultural Organization (FAO) and the World Health Organization (WHO) have developed various guidelines and tools for pesticide risk reduction, including those related to highly hazardous pesticides. Do not overuse or misuse the chemicals.

By adopting these ethical principles and guidelines, farmers and other stakeholders can contribute to a more sustainable and responsible approach to agrochemical management, minimizing risks to human health and the environment while ensuring food security.

ii) Integrated Pest management

IPM is an approach which uses a variety of techniques, including **cultural practices, biological control, and chemical control** (judicious use of pesticides) to keep pest populations below economically damaging levels. It focuses on preventing pest problems, monitoring pest activity, and using the least toxic control methods first.

It involves regular monitoring of pest populations and damage levels to determine when control measures are needed. IPM reduces the usage of pesticide thereby protecting the soil, environment, animals and human health. It is a cost-effective approach as it reduces the frequent use of pesticides. IPM practices can lead to healthier crops that are more resilient to pest and disease outbreaks.

iii) Promoting organic farming

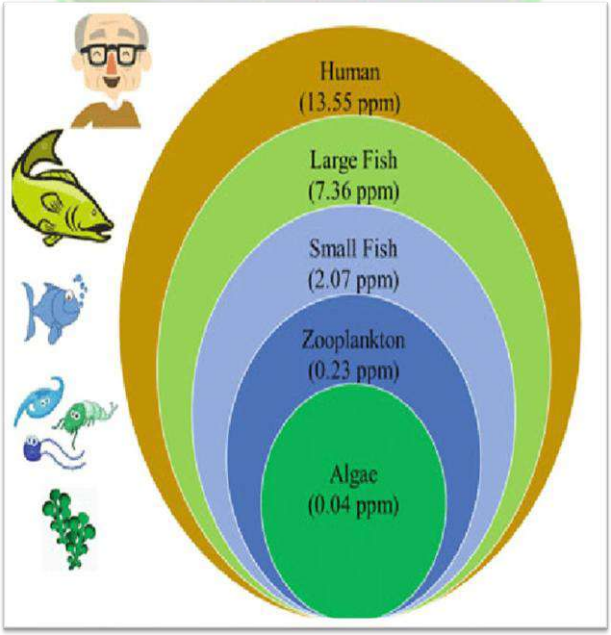
It aims to produce healthy food while minimizing environmental impact and promoting long-term sustainability. Organic farming emphasizes the use of natural processes like crop rotation, composting, and biological pest control**.**

Organic farming emphasizes the use of natural processes like crop rotation, composting, and biological pest control. Synthetic pesticides, herbicides, fertilizers, and genetically modified organisms (GMOs) are prohibited. It prioritizes building and maintaining healthy soil through practices like composting, cover cropping, and reduced tillage. These practices often support a greater diversity of plants and animals, including beneficial insects and pollinators. Moreover, it enhances soil fertility, structure, and water retention. Organic farming minimizes pollution.

iv) Do not use banned or persistent pesticides

There are many pesticides banned in India for manufacture, import and use. Some of the examples are Alachlor in 2018, Dicofol in 2023 etc. The list of pesticides banned in India is regularly updated on the website of **The Directorate of Plant Protection, Quarantine and Storage.** The use of DDT in Agriculture is withdrawn**.**

BIOMAGNIFICATION OF PESTICIDES (DDT) IN DIFFERENT TROPHIC LEVELS OF FOOD CHAIN



SOURCE: researchgate.net

In very special circumstances warranting the use of DDT for plant protection work, the state or central Govt. may purchase it directly from M/s Hindustan Insecticides Ltd. to be used under expert Governmental supervision. As DDT is highly persistent in soil with half- life ranging from 2 to 15 years (half of DDT breaks down in soil it takes 2 to 15 years). It is easily transported through runoff, volatilization, photolysis and biodegradation. The breakdown of products (like DDE and DDD) can accumulate in plants and fatty tissues of animals and results in biomagnification

Promoting sustainable agriculture

Sustainable agriculture is not just an environmental concern; it's an economic imperative and a social responsibility. It involves adopting farming practices that are environmentally responsible, economically viable, and socially beneficial. This means focusing on practices that conserve natural resources, promote healthy ecosystems, and support local economies. Key elements include reduced reliance on harmful chemicals, soil conservation, water efficiency, biodiversity, and

Promoting sustainable agriculture is crucial for ensuring long-term food security, environmental protection, and economic viability within the agricultural sector. By embracing practices that enhance soil health, conserve resources, and minimize environmental impact, we can create a more resilient and sustainable food system for current and future generations.

Impact of climate change on pesticide use

- Climate change-induced stresses like drought and heat waves can weaken crops, making them more susceptible to pests and diseases, and thus necessitating more pesticide application.
- Increased pesticide use can lead to greater pesticide runoff into water bodies, soil contamination, and potential harm to non-target organisms, including beneficial insects and pollinators. Furthermore, increased pesticide use can negatively impact human health through increased exposure and potential for pesticide poisoning.
- Pesticide use and degradation can also release volatile organic compounds and disrupt soil microbial activity, further exacerbating climate change.

Conclusion

The future of agrochemicals in India is promising, with a strong emphasis on sustainability, technological advancements, and a growing global market. India is poised to

become a major player in the global agrochemical industry, driven by increasing food security concerns, export opportunities, and government support. The industry is expected to see a shift towards eco-friendly and bio-based solutions, alongside the adoption of precision farming techniques.

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COCONUT CULTIVATION TECHNOLOGY

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Introduction

India is ranked as first largest producer of coconut in the world. The crop is grown in 2.08 million ha producing 23954 million nuts annually with productivity of 11505 nuts/ha. Four major Southern States viz., Kerala, Karnataka, Tamil Nadu and Andhra Pradesh together accounts for 90 per cent of coconut production. Kerala accounts for largest area (36.89 per cent of area) followed by Karnataka (25.20 per cent) and Tamil Nadu with (22.01 per cent).

Climate:

It requires an equatorial climate with high humidity. The ideal mean annual temperature is 27°C with 5-7°C diurnal variation. All well distributed rainfall of 1300-2300 mm per annum is preferred.

Soil:

Coconut is grown in different soil types such as laterite, coastal sandy, alluvial and also in reclaimed soils of the marshy lowlands. It tolerates salinity and a wide range of pH from 5.0 to 8.0. Proper drainage, good water holding capacity, optimum soil moisture and absence of rock or any hard substratum within 2 m of the surface are ideal for better growth and performance of the palm.

Varieties of Coconut:

a. Dwarf Varieties

- Shorter in stature
- Life span is short as compared to the tall
- Height: 5-7 m

- Average life span: 40-50 years
- Bearing starts from 3-4 years after planting
- Nuts are smaller and the copra soft, leathery and low in oil content.
- Grown mainly for establishing parent material in hybrid seed production and for the tender coconuts. Eg. Chowghat Orange Dwarf (COD), Chowghat Green Dwarf (CGD), Chowghat Yellow Dwarf (CYD), Malayan Green Dwarf (MGD), Malayan Orange Dwarf (MOD), Malayan Yellow Dwarf (MYD) and Ganga Bondam (GB).



Chowghat Orange Dwarf (COD) | *Chowghat Green Dwarf (CGD)* | *Malayan Green Dwarf (MGD)*

Malayan Yellow Dwarf (MYD) | *Malayan Orange Dwarf (MOD)* | *Ganga Bondam (GB)*

b. Tall varieties: –

- Taller in stature
- Life span is longer as compared to dwarf
- Height: 15-18 m
- Average life span: 60-80 years
- Bearing starts from 7-10 years after planting
- Good quality copra, oil and fiber
- Cultivars named after the place where they are largely cultivated. Eg : West Coast Tall (WCT), East Coast Tall (ECT), Laccadive Ordinary, Laccadive micro, Tiptur Tall, Kappadam, Komadan and Andaman Ordinary



West Coast Tall (WCT) | East Coast Tall (ECT) | Laccadive micro

c. Hybrids:

- The inter varietal crosses of two morphological forms of coconut
- Earliness in flowering
- Increased yield, higher quantity and better quality of copra and oil when compared to the parents.
- Tall x Dwarf (TxD): Tall - female mother palm & dwarf - male parent
- Dwarf x Tall (D x T): Dwarf - female parent & tall - male parents.



Kerasankara (WCT x COD) | Chandralaksha (LCT x COD)

Lakshaganga (LCT x GB) | .....

Chandrasankara (COD x WCT) | Kalpa Sankara (CGDxWCT), | Kalpa Samrudhi (MYDxWCT),

Production of quality seedlings in nursery

a. Selection & preparation of site

- ✓ Well drained
- ✓ Light textured soil
- ✓ Not too much shade

b. Selection of mother palms

- ✓ Regular bearing
- ✓ Yield not less than 80 nuts/annum
- ✓ Age – Dwarf - 5 years after reaching full bearing capacity, Tall-20 years or more
- ✓ More than 30 fully opened leaves
- ✓ Bearing 12 bunches of nuts
- ✓ Shape of crown: Spherical or semi-spherical
- ✓ Petioles: short and stout and be able to give effective support to the coconut bunches.
- ✓ Bunch stalks: short and strong and should not have the tendency of droop down.



Avoid palms which have the following characteristics

◊ Long, thin and pendulous inflorescence stalks

◊ Long, narrow, small sized or barren nuts

◊ Alternate bearing tendency.

◊ Immature nuts shedding in large numbers

◊ Grown under favourable environmental conditions.

c. Selection of seed nut

◊ Nuts of medium size and oblong shape

◊ Age – above 11month old

◊ Husked nuts more than 600 g weight

◊ Mean copra content 150g per nut or more

d. Collection seed nuts

◊ Time: Vary from region to region according to the seasonal conditions

◊ Ideal time - December to May ◊ Lowering of bunches by ropes

e. Storage of seed nuts

◊ Do not sow immediately after harvest

◊ To get better quality seedlings, the seed nuts of tall and hybrid are to be air cured for one month followed by sand curing

◊ Store for 60 days till the husk becomes dry

◊ Storing - prepare 8cm sand layer – keep seednuts with stalk end up-cover with sand – keep upto - five layers f. Bed preparation ◊ Width – 1.5 m

◊ Length – Convenient

◊ Space between beds – 75 cm

◊ Spacing Between rows – 30 cm

◊ Spacing between nuts – 30 cm

◊ No. of rows per bed – 4- 5

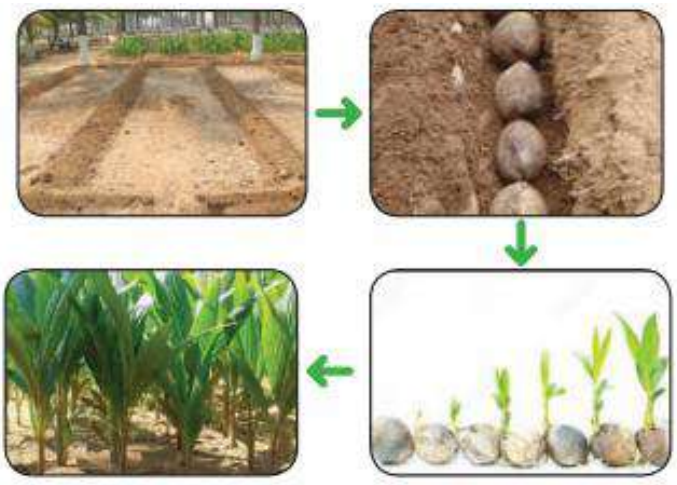
◊ Sow in trenches 25-30 cm deep

◊ Method of planting – two types Vertical and Horizontal

◊ Time of sowing – May-June

g. Care and management of nursery

- ✓ Keep nursery beds free of weeds
- ✓ Irrigation – once in two days
- ✓ Termite attack – dust soil and nuts with Chlorpyrifos
- ✓ Fungal infection – Spray 1% Bordeaux mixture/copper fungicide



Selection of good quality seedling

- ✓ 9-12 month old seedling
- ✓ At least four leaves for 9 month old seedling
- ✓ Six to eight leaves for 10-12 month old seedling
- ✓ Early germination, rapid growth & seedling vigour
- ✓ Collar girth : 10-12 cm
- ✓ Early splitting of leaves
- ✓ Remove seednuts do not germinate within 6 months after sowing
- ✓ Percentage of recovery: 60-65 per cent.



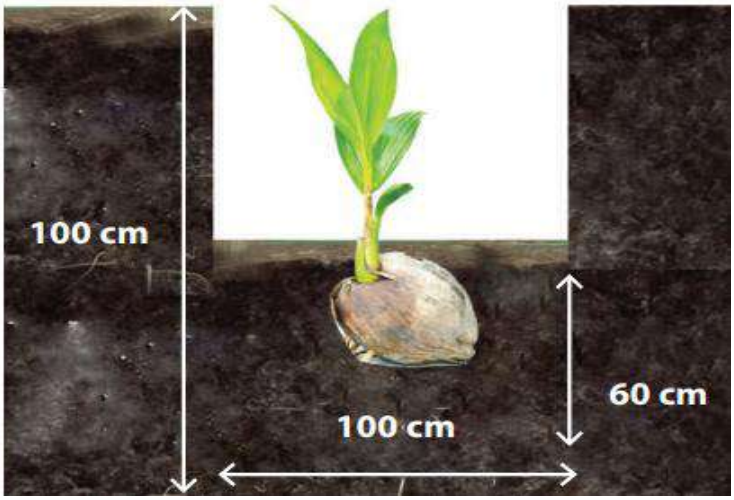
Field preparation and planting

a. Planting Season:

- ✓ Depends upon the local climatic condition
- ✓ Varies from State to State
- ✓ Proper time of planting: at the advent of the monsoon
- ✓ Under assured irrigation: planting at any time.
- ✓ In low lying areas: planting either after the monsoon or long before the monsoon.

b. Preparation of land and planting of seedlings

- ✓ Size of pit in loamy soil – 1m x 1m x 1m
- ✓ Size of pit in laterite soils – 1.2 m x 1.2m x 1.2m
- ✓ Size of pit in sandy soil – 0.75m x 0.75m x 0.75 m
- ✓ Lateritic area – 2kg common salt per pit can be applied
- ✓ Fill pit to a height 60 cm with top soil
- ✓ Plant seedlings at the centre of the pit
- ✓ Ideal time of planting: May
- ✓ In low lying areas – plant seedlings in September

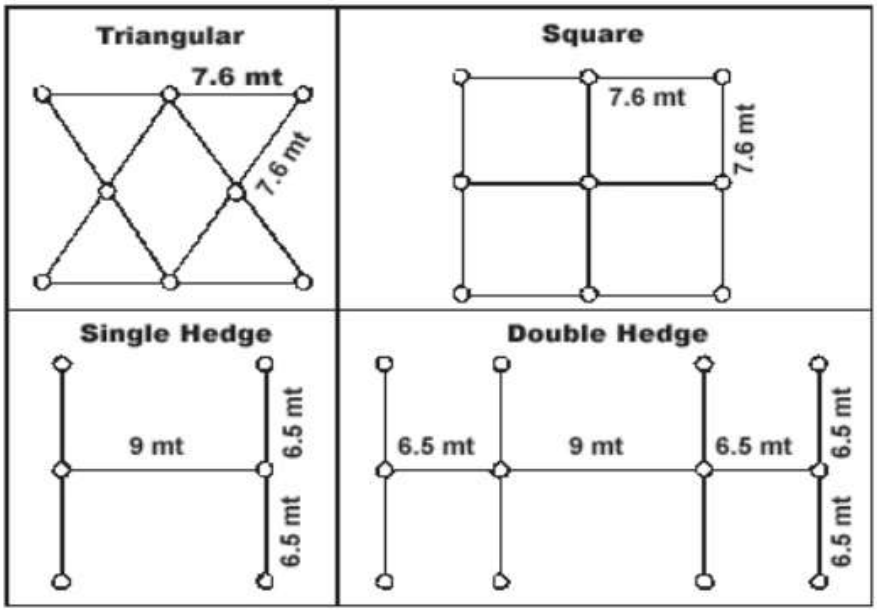


c. Spacing:

A spacing of 7.5 x 7.5 m is generally recommended for Coconut. Spacing depends upon the planting system, soil type etc.

Planting system	Spacing	Approximate number of plants/ ha
Triangular	7.6 m	198

Square	7.6m ×9m	170-120
Single hedge	6.5 m in the rows 9 m between the rows	220
Double hedge	6.5m * 6.5 min rows 9m between pairs of rows	280



d. Irrigation & Shading:

- ✓ 45 litres of water once in 4 days has been found to be satisfactory in all soil types.
- ✓ Provide adequate shade to the transplanted seedlings.

d. Weeding and interculture:

- ✓ Keep the pits free of weeds by periodical weeding
- ✓ Remove the soil covering the collar of seedlings.
- ✓ As the seedlings grow - Fill up the pits gradually by cutting the sides.



Manuring and fertilizer

a. Lime application

- ✓ Apply lime or dolomite 1 kg/palm/year if soil is acidic
- ✓ Time- 15 days before fertilizer application

b. Manuring and Fertilizer application

- ✓ Regular manuring from the - first year of planting is essential to achieve higher productivity.
- ✓ Organic manure: 20 - 50 kg per palm per year with the onset of south west monsoon, when soil moisture content is high.
- ✓ Different forms of organic manures like compost, farm yard manure, bone meal, - fish meal, blood meal, neem cake, groundnut cake etc. could be made use for this purpose.
- ✓ Lime or dolomite – 1 Kg/palm/year
- ✓ Magnesium sulphate – 0.5 Kg/palm/year
- ✓ Fertilizer recommendation: 500:320:1200 g N,P2 O5 ,K2 O per palm per year

Method of fertilizer application

- ✓ Make circular basin at a radius of 1.8 - 2.0 m from the base of the palm and 25 cm deep
- ✓ Apply 1 Kg lime/dolomite prior to fertilizer application to neutralize soil pH.
- ✓ Apply organic manure – 10 kg/pit in the - first three years & 15-25 kg after 3 years of planting
- ✓ Rainfed conditions – apply fertilizers in two split doses, 1/3rd at the time of early southwest monsoon showers in April-June and 2/3rd in September-October
- ✓ Irrigated conditions – apply fertilizers in three or four equal doses in April, May, august-September, December and February-March.

Irrigation

- ✓ Irrigate palms during summer months
- ✓ 600 – 1600 litres of water/irrigation/palm in a basin of 1.8 m radius based on soil texture
- ✓ Drip irrigation in case of scarcity of water
- ✓ 3-4 drippers are given per palm in drip irrigation
- ✓ It saves water, energy, labour and increase plant growth and yield.



Drought management

i. Husk burial:

- ✓ Burying of fresh or dried coconut husk around the palm
- ✓ Husk can be buried in circular trenches taken around the palm at a distance of 2m from the trunk
- ✓ Trenches may be of 0.5 m width and depth
- ✓ Husk can be buried in linear trenches taken 3 m away from the trunk between rows of palms
- ✓ Husks are to be placed in layers with concave surface facing upwards and covered with soil
- ✓ Beneficial effect last for about 5-7 years
- ✓ Instead of husk, coir pith can be buried @ 25 kg per palm per year.



ii. Mulching

- ✓ Mulch coconut basin with green/ dry leaves
- ✓ Mulching adds organic matter and reduces the soil temperature
- ✓ Application of lime solution on the trunk up to a height of 2-3 m at the start of the summer season.

iii. Green manure and cover crops

- ✓ Sow green manure and cover crop seeds during April – May with the onset of pre-monsoon rains
- ✓ Sow cow pea seeds in the basins taken at a radius of 2 m from the base of the palm
- ✓ Uproot the entire plant when few plants start flowering
- ✓ Incorporate the uprooted plants into the soil during August-September
- ✓ Cover the basins with soil
- ✓ Green manure crops: Sunhemp, Kolinji, Hairy indigo, Kudzu
- ✓ Cover crops: *Calapagonium muconoides, Mimosa invisa, Stylosanthes gracilis*
- ✓ Sowing 100 g cow pea in basin provides 15-25 kg green manure and will provides 100-200 g Nitrogen.

Intercropping & mixed cropping

- ✓ Schedule inter/mixed crop based on canopy size, age and spacing of palms
- ✓ Palms in the age group of 8-25 years are not suitable
- ✓ Cereals: Rice, maize
- ✓ Legumes and pulses: Groundnut, horse gram, cowpea

  Tubers: Tapioca, sweet potato, yams, colocasia.
- ✓ Spices and condiments: Ginger, turmeric, chilly, pepper, nutmeg, cinnamon, clove
- ✓ Fruit plants: Banana, pineapple, papaya
- ✓ Beverage crop: Cocoa
- ✓ Fodder grasses: Hybrid Napier, guinea grass

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FISHING SMART: THE DIGITAL TOOLS LEADING THE SUSTAINABILITY WAVE

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Abstract

Fisheries is a sunrise sector where resources are renewable but if exploited then the resources may reach to a stage of extinction. So, following sustainable practices is most important. Several ocean animals have gone extinct throughout history, with some notable examples including the Megalodon shark, Steller's sea cow, and various marine reptiles like the Mosasaurus where unsustainable fishing practices are one of the reasons. The following study gives a brief about the mobile applications that support sustainable fishing. At present the fastest mode of communication is through mobile network, therefore the below mentioned apps help in increasing productivity while maintaining sustainability. The following article also addresses the challenges in using these apps asual as the future innovations required for sustainable fishing.

Introduction

Sustainable fishing refers to fishing practices that ensure fish populations can replenish themselves naturally, maintaining healthy marine ecosystems and supporting human livelihoods. It involves managing fisheries to prevent overfishing and minimize negative impacts on the environment. This includes understanding fish populations, setting catch limits, and employing fishing methods that reduce bycatch and habitat damage.

Mobile apps play a crucial role in promoting sustainable fishing practices by providing fishers with access to information, tools, and resources that enhance their ability to make informed decisions and manage their operations more efficiently and responsibly. According to Sharma, & Dhenuvakonda, (2019) there are 18 Angling ,20 Aquaculture, 10 Aquarium management,61 Marine fisheries and 15 Fisheries governance apps. Among the 124 apps the apps the support sustainable fishing are mentioned in the following study.

Role of mobile apps

1. Information Dissemination and Decision-Making:

Apps can provide fishers with access to real-time information on weather conditions, ocean currents, and fish stock distribution, enabling them to make informed decisions about when and where to fish, optimizing their routes, and avoiding dangerous situations. Apps can offer GPS navigation and mapping features, helping fishers locate fish shoals, navigate safely, and avoid protected areas or sensitive habitats. Apps can provide up-to-date information on fish prices, market trends, and buyer demand, allowing fishers to maximize their earnings and minimize post-harvest losses. Apps can assist fishers in understanding and adhering to fishing regulations, including catch limits, gear restrictions, and reporting requirements

2. Enhancing Efficiency and Reducing Waste

Apps can provide guidance on best fishing practices, helping fishers to minimize bycatch (unintended catch of non-target species), reduce fuel consumption, and improve overall fishing efficiency. Apps can help fishers track their catches, monitor fish stocks, and identify areas where fishing pressure is high, enabling them to adjust their fishing strategies to prevent overfishing and depletion of fish populations. Apps can provide information on proper fish handling techniques, storage, and transportation, minimizing spoilage and waste and maximizing the value of their catch.

3. Promoting Sustainability and Conservation

Mobile apps can be used to educate fishers and the wider community about the importance of sustainable fishing practices, marine conservation, and the impact of overfishing. Apps can facilitate the collection and reporting of data on fish catches, fishing effort, and environmental conditions, which can be used to monitor fish stocks, assess the effectiveness of conservation measures, and inform fisheries management decisions. Apps can

foster collaboration and communication among fishers, scientists, policymakers, and other stakeholders, promoting a participatory approach to fisheries management and conservation.

4. Addressing Challenges in Small-Scale Fisheries

Mobile apps can bridge the information gap between large-scale commercial fisheries and small-scale, often remote, fishing communities, empowering them to participate more effectively in the management and conservation of fisheries. By providing access to market information, optimizing fishing practices, and reducing post-harvest losses, mobile apps can contribute to improved livelihoods for fishers and their families.

The review provided by Calderwood, J. (2022) states that mobile apps function in (1) data collection, (2) providing access to marketing opportunities, (3) lifesaving tools, and (4) ways to communicate with the wider fleet.

Sustainable Fishing apps

ABALOBI

The ABALOBI app started in 2015 in South Africa as part of a larger effort to help small-scale fishers. It is built as a tool to manage information for the small-scale fishing industry. This suite of apps (Fisher, Marketplace, Monitor) supports small-scale fishers in managing their activities, including catch logging, effort tracking, financial management, and accessing market information. App Acts as a digital logbook where fishers record catch details (species, quantity, location, gear, time), expenses, and income—with built-in analytics and forecast tools. This allows fishers to connect directly with restaurants and customers, letting them share their daily catch, get fair prices, fast payments, and full tracking of their fish from the boat to the plate. App Provides scientists and regulators with real-time, community-generated data to support sustainable stock assessments and informed management decisions. The app aims to Empower small-scale fishers, by providing them with access to technology and market information. Improve fisheries management, Through data collection and monitoring. Promote transparency and traceability by enabling fishers to record and share their catch data. Help fishers sell their catch by linking them directly to buyers.

I ANGLER

The term "angler app" generally refers to mobile applications designed for anglers, offering various features to enhance their fishing experience. These apps can range from basic tools for logging catches and locations to more advanced platforms for planning trips, accessing

real-time weather and fishing forecasts, and connecting with other anglers. This app Records details of catches, including species, size, location, and photos. The application functions in Saving fishing spots, either manually or with GPS, and marking points of interest like boat ramps and access points. It Provides real-time weather information, tide predictions, and solunar data to help anglers plan their trips. The app provides Access to information on local fishing regulations and promotes responsible fishing practices.

mKRISHI ® Fisheries

This app, developed by the Indian government, likely offers information and support related to fisheries and aquaculture practices. The mKRISHI® Fisheries app is a mobile application designed to assist fishermen by providing real-time information relevant to their fishing activities. Developed in collaboration with various organizations, including the Indian Council of Agricultural Research (ICAR), Tata Consultancy Services (TCS) Innovation Lab, and Indian National Centre for Ocean Information Services (INCOIS), the app provides information on Potential Fishing Zones (PFZ), weather conditions, and other crucial data, all in local languages with easy-to-use icons. The app helps fishermen identify areas with high potential for fish catch, enabling them to optimize their fishing trips and reduce fuel consumption. According to the results of the study conducted by sHertzum *et al*., 2018. Fishers in Alibaug found fishing shoals easily with the help of maps provided in the app. The app helps fishermen identify areas with high potential for fish catch, enabling them to optimize their fishing trips and reduce fuel consumption. The app delivers information in local languages, making it accessible to a wider range of fishermen. The app delivers information in local languages, making it accessible to a wider range of fishermen. The app's ability to identify potential fishing zones and provide relevant information has led to an increase in catch for some fishermen. The app's ability to identify potential fishing zones and provide relevant information has led to an increase in catch for some fishermen.

CIBA Shrimp app:

Developed by the ICAR-Central Institute of Brackish water Aquaculture (CIBA), this app provides information on shrimp farming, including risk assessment modules. It also works offline. CIBA Shrimp App refers to two related mobile applications developed by the Indian Council of Agricultural Research - Central Institute of Brackish water Aquaculture (ICAR-CIBA): Vanami Shrimp app and CIBA Shrimp Krishi. These apps are designed to support

shrimp farmers by providing technical information, farm management tools, and a platform for communication with experts. Both apps provide technical information and support to shrimp farmers, extension personnel, and entrepreneurs. CIBA Shrimp Krishi offers tools for recording and monitoring farm activities, helping farmers manage their operations effectively. Both apps provide a platform for farmers to connect with scientists and experts, ask questions, and receive timely guidance. Vanami Shrimpapp includes a module for shrimp disease diagnosis, allowing farmers to identify potential diseases by comparing their farm conditions with provided images of symptoms. According to Abbibrinda *et al*. (2020), the most recent update of the application offers features like a risk assessment tool, advisory support, compliance information on government policies, and disease diagnosis capabilities. Importantly, it also operates in offline mode, making it accessible without an internet connection.

SAMUDRA

The Indian National Centre for Ocean Information Services (INCOIS) developed this app to provide comprehensive ocean-related information, including weather forecasts, disaster alerts, and advisories for seafarers and the fishing community. The Indian National Centre for Ocean Information Services (INCOIS) of the Ministry of Earth Sciences launched a mobile application known as “SAMUDRA” (Smart Access to Marine Users for ocean Data Resources and Advisories) for comprehensive information on all ocean related services, useful for both seafarers and the fishing community.

Seafood Watch

While not solely Indian, the Seafood Watch app provides information on sustainable seafood choices, which is relevant to promoting sustainable fishing practices. The Seafood Watch app is a mobile application created by the Monterey Bay Aquarium to guide consumers towards sustainable seafood choices. It provides recommendations based on the environmental impact of different seafood, categorizing them as "Best Choice," "Good Alternative," or "Avoid". The app also helps locate nearby businesses serving sustainable seafood options. The Seafood Watch app is a mobile application created by the Monterey Bay Aquarium to guide consumers towards sustainable seafood choices. It provides recommendations based on the environmental impact of different seafood, categorizing them as "Best Choice," "Good Alternative," or "Avoid". The app also helps locate nearby businesses serving sustainable seafood options.

Challenges and limitations in using Sustainable fishing apps

Though there many advantages using the above-mentioned apps challenges still exist. There's no universally agreed-upon standard for data collection via angler apps, leading to inconsistencies in how information is gathered and reported. Managing the vast amounts of data generated by these apps can be challenging, especially for fisheries management agencies with limited resources. The voluntary nature of app usage can lead to inaccurate or incomplete data, requiring verification or compulsory reporting mechanisms to ensure reliability. Developing and maintaining sustainable fishing apps can be expensive, potentially hindering widespread adoption, especially for smaller fishing operations or in developing countries. The quality and consistency of data collected can vary, potentially impacting the effectiveness of these apps for fisheries management. A significant portion of the fishing population may not have access to smartphones or possess the necessary digital literacy to effectively use these apps. The voluntary nature of participation in some apps can result in incomplete or biased datasets, as not all fishermen may choose to participate or report accurately. In developing countries, factors like limited technological infrastructure, low digital literacy, and lack of financial incentives can hinder the adoption of these technologies.



Figure 1: Pictorial representation of different apps helping for sustainable fisheries

Some apps may lack features or have a poor user experience, which can discourage fishermen from using them. Some fishermen may be unaware of the benefits of using sustainable fishing apps or may not trust the technology, hindering adoption. Concerns about data security and privacy can also be a barrier to adoption, particularly if fishermen are unsure how their data will be used. Integrating these apps with existing fisheries management systems can be challenging, requiring coordination and collaboration between different stakeholders. Ensuring that sustainable fishing practices are followed and that data is used effectively for management requires enforcement and compliance mechanisms, which can be difficult to implement.

Future frontiers

Future frontiers in sustainable fishing apps involve leveraging technologies like AI, drones, and eDNA analysis to enhance monitoring, improve selectivity, and combat illegal fishing practices, ultimately promoting more responsible and efficient fishing operations.

Some potential advancements:

1. AI-powered Fishing Systems

AI can analyse vast amounts of data from various sources, including satellite imagery, sonar, and underwater sensors, to identify fish stocks, track fishing vessels, and detect illegal fishing activity. AI algorithms can be used to design more selective fishing gear, minimizing bycatch (the capture of non-target species) and reducing damage to marine ecosystems. AI can help predict fish movements and stock abundance, enabling fishers to optimize their fishing strategies and minimize their environmental impact. AI can provide fishers with real-time information and recommendations on the best fishing locations, gear settings, and catch limits based on current conditions and stock assessments.

2. Drone Technology:

Drones equipped with cameras and sensors can be used to monitor fishing vessels, track their movements, and identify any potential illegal activities. Drones can be used to survey fish populations, assess their health, and monitor their distribution. By identifying optimal fishing locations and reducing search time, drones can help fishers minimize their fuel consumption and overall fishing effort.

3. eDNA Analysis:

Environmental DNA (eDNA) analysis can be used to identify the presence of different fish species in a given area, even in low concentrations. eDNA can be used to detect the presence

of threatened or endangered species in fishing gear, helping to minimize bycatch. eDNA can be used to identify the origin of fish products, helping to combat illegal, unreported, and unregulated (IUU) fishing.

4. Other Emerging Technologies

Blockchain can be used to create transparent and traceable seafood supply chains, ensuring that consumers know where their fish comes from and that it was caught using sustainable practices. IoT sensors can be deployed on fishing vessels and in the marine environment to collect data on water temperature, salinity, and other factors that can affect fish populations. Machine learning algorithms can be used to analyse fish behaviour and improve the selectivity of fishing gear.

5. Collaboration and Data Sharing

Engaging fishing communities in the development and implementation of sustainable fishing technologies is crucial. Creating platforms for sharing data on fish stocks, fishing practices, and market information can help improve the effectiveness of sustainable fishing efforts. International collaboration is essential for addressing the global challenges of overfishing and IUU fishing.

Conclusion

Sustainable fishing apps offer a promising avenue for enhancing the sustainability of fisheries by providing fishers with valuable information and tools for responsible fishing practices, promoting transparency, and contributing to data collection for fisheries management. They can improve efficiency, reduce costs, and ultimately help ensure the long-term health of fish populations and marine ecosystems. The apps being effective the usage and availability of apps is increasing day by day. Calderwood, J. (2022) stated that the number of mobile applications continues to grow steadily, with approximately 1.85 million apps available on Apple's iOS App Store and around 2.56 million accessible to Android users via the Google Play Store as of 2020.

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FUTURE FARMING: MICROGREENS FOR HEALTH IN SOIL-FREE SPACES

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1. Introduction: A Green Revolution on Your Plate

In a world searching for sustainable solutions and nutrient-rich diets, one small green is making a big impact: **microgreens**. These vibrant baby plants are not only a chef's delight but also a nutrition powerhouse. Even more exciting is the fact that they can thrive *without soil*, making them ideal for modern, urban lifestyles. Welcome to the world of **soilless microgreen farming** — the future of agriculture right in your living room.



2. What Are Microgreens? The Power of Young Plants

Microgreens are young, tender seedlings of vegetables and herbs that are harvested just after the first set of true leaves appear—typically 7 to 21 days after germination. Though they are small in size, they pack an extraordinary amount of flavor, color, and—most importantly—nutrition. Microgreens are not the same as sprouts; while sprouts are germinated seeds grown in

water and eaten whole, including the seed and root, microgreens are grown in a medium like soil or cocopeat and are harvested above the root line. Popular varieties include mustard, radish, broccoli, beetroot, fenugreek, sunflower, and basil. These vibrant little greens have gained immense popularity in both gourmet cuisine and home kitchens, not only because of their aesthetic appeal and intense taste but also due to their health-promoting properties. Studies have shown that microgreens can contain 4 to 40 times more vitamins and antioxidants compared to their mature plant counterparts. For example, red cabbage microgreens have been found to be rich in vitamin C and vitamin K, both essential for immunity and bone health. Their ability to grow quickly, in limited space, with minimal resources, makes them ideal for urban settings and soilless farming techniques like hydroponics. From boosting nutrient intake to enhancing food presentation, microgreens are a powerful example of how nature delivers big benefits in small packages.



3. **Why Go Soil-Free? Understanding Soilless Cultivation**

Soilless cultivation, also known as soilless farming, is a modern method of growing plants without using traditional soil. Instead, crops are grown using alternative media such as cocopeat, perlite, vermiculite, rockwool, or even just nutrient-rich water, as seen in hydroponics and aeroponics. This approach is gaining popularity for several practical and environmental reasons. First, it allows plants to grow in a **clean and controlled environment**, minimizing the risks associated with pests, weeds, and soil-borne diseases. This means fewer chemical inputs like pesticides and herbicides are needed, making the system more sustainable and safe for consumers. Second, soilless farming is **highly space-efficient**. It can be done on rooftops, balconies, and even indoors using vertical farming racks and LED grow lights — making it an ideal solution for **urban areas with limited land availability**. Third, these systems are

extremely water-efficient, often using up to 90% less water than traditional soil farming by recycling nutrient solutions. In regions facing water scarcity or poor soil quality, this becomes a significant advantage. Moreover, the faster growth rate and year-round production cycles mean growers can achieve multiple harvests in a short time, increasing productivity. As we face the challenges of climate change, land degradation, and urban expansion, soilless cultivation offers a resilient, eco-friendly alternative to feed the growing global population with fresh, healthy, and locally-grown produce — without relying on fertile land.

4. **Soilless Growing Systems for Microgreens: Hydroponics, Cocopeat, and More**

- **Hydroponics**: Microgreens are grown with their roots suspended in nutrient-rich water.
- **Cocopeat Trays**: Coconut husk fiber provides a lightweight, moisture-holding base.
- **Biodegradable Mats**: Jute, hemp, or felt mats offer sterile, easy-to-use mediums.
- **Vertical Farming Racks**: Layered trays under LED lights maximize space and output.

These systems use **90% less water** than soil farming — a boon for water-scarce regions.

5. **Nutrition Packed in Every Leaf: The Health Benefits of Microgreens**

Microgreens contain concentrated levels of:

- **Vitamins A, C, E, and K**
- **Iron, magnesium, potassium**
- **Antioxidants and polyphenols**

Their regular consumption helps boost immunity, regulate blood sugar, improve digestion, and even reduce the risk of chronic diseases like heart conditions and diabetes.

6. **Microgreens for Urban Living: Compact Farming in Kitchens and Balconies**

In today's fast-paced urban life, where space is limited and time is scarce, microgreens offer a simple and efficient way to reconnect with nature and improve daily nutrition. These tiny greens—harvested just 7 to 14 days after germination—can be grown easily in small trays on windowsills, balconies, rooftops, or even kitchen counters using soilless media like cocopeat, jute mats, or hydroponic grow pads. Unlike traditional gardening, microgreen cultivation requires no deep soil, minimal sunlight, and very little water. With basic care—daily misting and moderate light—urban residents can grow nutrient-rich greens like mustard, radish, fenugreek, sunflower, and basil right in their apartments. These greens are packed with vitamins, antioxidants, and minerals, offering a concentrated dose of health benefits in every bite. For people living in flats, hostels, or homes without open space, microgreens are a sustainable and

rewarding way to grow fresh food. They also contribute to mental well-being, reduce food miles, and provide a sense of self-reliance. In short, microgreens represent a green revolution in miniature, bringing farming to the heart of urban living—clean, compact, and full of life.

7. **Environmental Benefits of Soilless Microgreen Farming**

- **Zero soil erosion**
- **Minimal water usage**
- **No synthetic pesticides**
- **Reduces carbon footprint of food transport**
- **Utilizes kitchen waste water (after filtration) in hydroponics**

This eco-friendly farming method supports both **planet and plate**.

8. **Start Your Own Soilless Microgreen Garden: A Simple Guide**

What You Need:

- Tray or container with holes
- Cocopeat or jute mat
- Microgreen seeds
- Spray bottle
- Sunlight or grow lights

Steps:

1. Soak seeds for 6–8 hours.
2. Spread evenly over moistened medium.
3. Cover for 2–3 days (germination).
4. Uncover and mist daily.
5. Harvest in 7–12 days by cutting above the root.

Growing microgreens at home without soil is one of the easiest and most rewarding ways to bring fresh, nutrient-rich food into your daily diet. All you need is a shallow tray, a growing medium like cocopeat or a jute mat, clean water, and microgreen seeds such as mustard, fenugreek, sunflower, or radish. Begin by soaking the seeds for 6 to 8 hours to enhance germination. Next, spread the moistened growing medium evenly in the tray and drain the soaked seeds onto it in a single layer. Cover the tray for the first 2 to 3 days to allow dark, moist conditions for sprouting. Once germinated, uncover the tray and place it in indirect sunlight or under a grow light. Mist the seedlings gently twice a day to keep the medium moist but not

soggy. Within 7 to 10 days, your microgreens will be ready for harvest. Simply snip them just above the medium using clean scissors, rinse, and enjoy. These mini greens are perfect in salads, sandwiches, soups, or as colorful garnishes. This low-maintenance, high-reward practice not only provides a regular source of healthy food but also promotes eco-friendly living by reducing water usage, space needs, and food transport. Whether you live in an apartment, dorm room, or a rural home, starting a soilless microgreen garden is a simple step toward sustainable self-reliance.

9. **From Hobby to Business: Microgreens as an Emerging Agri-Enterprise**

Entrepreneurs and young farmers are turning to microgreens as a high-value crop. With **low startup costs, short crop cycles, and premium market prices**, microgreens are being sold to:

- Organic shops
- Gourmet restaurants
- Health-conscious customers
- Online delivery platforms

Startups in Bengaluru, Chennai, and Hyderabad are already scaling up indoor farms powered by solar energy and smart apps.

10. **Conclusion: Future of Farming, Future of Food**

The rise of **soilless microgreens** represents more than just a food trend. It's a vision for the future: farming that's **compact, clean, climate-resilient, and community-friendly**. Whether you're a student, a homemaker, or an urban farmer — the future is green, and it begins in your tray.As the global population rises and urbanization accelerates, the need for sustainable, space-efficient, and nutrient-rich farming systems has never been more urgent. Soil-free cultivation of microgreens represents a promising leap forward in how we grow our food. These compact greens, grown with minimal resources and harvested in just days, offer a powerful combination of health benefits and environmental sustainability. In an age of climate change, shrinking farmland, and dietary deficiencies, microgreens grown through hydroponics, cocopeat, or vertical farming offer a solution that is not only viable but visionary. They require less water, no chemical pesticides, and virtually no soil — making them ideal for cities, apartments, rooftops, and even classrooms. Beyond personal health, they empower individuals to take part in food production, reduce food miles, and create local food security. As we look to the future, microgreens are not just a food trend they are a symbol of the agricultural revolution we need.

By integrating technology with nature and efficiency with nutrition, soil-free microgreens offer a model of how the farms of tomorrow can fit in the palm of your hand — clean, green, and incredibly life-giving.

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PARTHENOCARPY IN VEGETABLE CROPS

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Abstract

Parthenocarpy describes the formation of fruits in the absence of fertilization, which can occur naturally or be induced through external interventions such as hormonal treatments or genetic manipulation. This phenomenon has become increasingly important in the breeding of vegetable crops, offering a pathway to enhance fruit quality and maintain productivity under unfavorable climatic conditions. In crops such as watermelon, cucumber, and tomato, parthenocarpy contributes to uniformity, improved shelf life, and greater consumer appeal. This article explores the underlying biological mechanisms, genetic factors, and cultivation techniques associated with parthenocarpic vegetable crops, with emphasis on their commercial relevance in protected and pollinator-limited environments.

KEYWORDS

Parthenocarpy, Seedless fruit, Triploid watermelon, Greenhouse cucumber, Hormonal regulation, Vegetable breeding

Introduction

Parthenocarpy is a biological process whereby fruits develop without the fertilization of ovules. This can be a naturally occurring trait or can be induced using plant hormones. It is particularly advantageous in growing conditions where pollination is hindered by stress factors such as extreme temperatures, inadequate light, or a decline in pollinator populations. The seedless fruits produced through this mechanism are often more appealing to consumers and

offer more predictable yields, making parthenocarpy a highly valued trait in vegetable production systems.

Seedless Watermelons – A Case of Induced Parthenocarpy

Although referred to as "seedless," certain watermelons contain small, immature seed traces. These are a byproduct of induced parthenocarpy, facilitated through the integration of triploid genetics and pollination-dependent fruit development.

- **Triploid Genetics:** Seedless watermelon varieties are generated by crossing diploid (2n) and tetraploid (4n) parents. The resulting triploid plants (3n) possess an unbalanced set of chromosomes, which disrupts normal seed formation, resulting in sterility. While these plants do not produce mature seeds, pollination is still essential to stimulate fruit development. Hence, diploid watermelons are interplanted to provide the necessary pollen.
- **Pollination Mechanism:** Although fertilization doesn't occur, the physical process of pollination initiates fruit formation. Without this trigger, fruit growth would not proceed.

Understanding the White Seed Traces:

The tiny white specks commonly observed in the flesh of seedless watermelons are undeveloped seed coats. These do not contain viable embryos and are therefore incapable of germination.

- These structures are soft and easily consumed, unlike the hard black seeds found in conventional varieties.
- Their presence is a residual result of incomplete fertilization events that begin but do not progress fully due to the chromosomal imbalance in triploid plants.
- As pollination acts as a growth signal, the fruit still initiates development even though functional seeds fail to mature.

Thus, what we perceive as "seedless" fruit actually contains only the remains of arrested seed formation—a consequence of the fruit's unique reproductive biology.

Parthenocarpy in Cucumbers

Parthenocarpy is a defining feature of many modern greenhouse cucumber cultivars, particularly European or "burpless" types. These varieties develop fruits without any need for pollination, enabling consistent production of seedless, high-quality cucumbers even in environments with limited insect activity.

Developmental Mechanism:

1. **Flower Biology**

   Cucumbers naturally bear both male and female flowers. In non-parthenocarpic types, the female flower must receive pollen to produce fruit. In contrast, parthenocarpic varieties bypass this requirement, allowing the ovary to mature into fruit independently.

2. **Initiating Fruit Growth Without Seeds**

   These varieties possess genetic modifications or natural traits that support fruit development in the absence of fertilization. Internal hormonal cues—primarily auxins, cytokinins, and gibberellins—facilitate this process:

   - **Gibberellins** promote elongation and fruit enlargement.
   - **Auxins** assist in the early stages of fruit set.
   - **Cytokinins** enhance cell division, resulting in well-formed, uniform fruit.

3. **Environmental Considerations**

   External conditions such as temperature, humidity, and light still impact fruit morphology. Poor environmental control may result in malformed or curled cucumbers despite the genetic potential for parthenocarpy.

Home Gardening of Parthenocarpic Cucumber Varieties:

- **Recommended Cultivars:** 'Diva', 'Tyria F1', and 'Corinto F1' are among the best suited for greenhouse or indoor cultivation.
- **Growing Tips:**
  - Use nutrient-rich, well-drained soil.
  - Maintain temperatures between 21–29°C.
  - Provide vertical support (stakes or trellises).
  - Ensure consistent irrigation.
  - Avoid planting near seeded cucumber types to prevent accidental cross-pollination, which may lead to seeded or malformed fruits.
  - Harvest regularly to promote continuous production.

Conclusion

Parthenocarpy represents a transformative advancement in vegetable crop production, offering a reliable alternative to pollination-dependent fruiting. By facilitating the development of seedless fruits, it contributes significantly to yield stability, especially under adverse

environmental conditions where pollinator activity is limited or inconsistent. Beyond resilience, parthenocarpic fruits often display superior market traits such as uniformity, enhanced shelf life, and consumer appeal. A deeper understanding of the genetic and hormonal mechanisms behind parthenocarpy, combined with strategic cultivation practices, can empower growers to adopt this trait effectively in both commercial farming and controlled environments. As the demand for high-quality, seedless produce continues to rise, integrating parthenocarpic varieties will play a vital role in the future of sustainable horticulture.

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PHOTOPERIODISM IN VEGETABLE CROPS: A NATURAL RHYTHM THAT SHAPES OUR FOOD

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Introduction

Plants, just like humans, are deeply attuned to time. But rather than clocks and calendars, they rely on nature's light cycles—sunrise, sunset, and seasonal shifts. This natural phenomenon, known as photoperiodism, plays a pivotal role in the life of plants, especially vegetable crops, guiding them when to grow, flower, or rest. As the Earth rotates on its axis and revolves around the sun, it creates predictable changes in daylight and temperature. While these changes are modest in tropical regions, in temperate zones they are striking, producing long days in summer and short days in winter. For plants, light is a more consistent environmental signal than temperature, making it an ideal cue to regulate development.

Photoperiod

Photoperiod refers to the duration of light in a 24-hour cycle. Even slight shifts in daylength can trigger remarkable changes in a plant's life cycle. For instance, some trees anticipate shorter days in autumn by halting growth and preparing for winter, while certain crops begin flowering or forming tubers in response to specific light durations. The ability of a plant to perceive and respond to these changes is governed by internal biological clocks—called circadian rhythms—fine-tuned by genes and environmental inputs.

Light

Light is sensed by special proteins called photoreceptors. In the model plant Arabidopsis thaliana, phytochromes respond to red and far-red light, transmitting signals that activate genes involved in daily and seasonal rhythms. These photoreceptors

communicate with a core group of genes like CCA1, LHY, and TOC1, which act like gears in an internal timekeeping machine. Their intricate feedback loops maintain a steady rhythm and adjust biological functions such as flowering and seed setting, depending on the time of day and season.

Interestingly, the molecular blueprint for these rhythms in Arabidopsis is shared across many crops. In vegetables, this insight helps us understand why spinach bolts quickly in long summer days or why onions form bulbs only under certain daylight hours. Some crops, like lettuce, are long-day plants that need more daylight to flower, while others, like potato, are short-day plants that begin tuber formation when nights are longer. The case of potato tuberization is particularly fascinating. Research has shown that the leaves, not the roots, perceive the photoperiod and send a chemical signal to initiate tuber formation underground. In fact, the same kind of signal that induces flowering in tobacco was found to trigger tuberization in potatoes when grafted—suggesting that flowering and tuber formation may share a common pathway.

As climate patterns shift and traditional growing seasons become less predictable, photoperiodism is gaining renewed attention in crop research. Breeding programs are now focusing on creating photoperiod-insensitive vegetable varieties that can thrive in varying daylengths and across different latitudes. Molecular tools like CRISPR and marker-assisted selection are helping scientists target key genes responsible for light sensitivity, opening new doors for adapting crops to a changing climate.

Photoperiodism not only influences flowering and yield, but also affects dormancy, quality, and shelf-life of vegetables. With the rise of controlled-environment farming, such as greenhouses and vertical farms, understanding and manipulating light cycles is now a powerful tool for year-round production of vegetables.

Conclusion

What began as a simple observation—that plants respond to light—has now evolved into a sophisticated field of plant science. From onions to potatoes, from greenhouses to genome editing, photoperiodism continues to shape the way we grow and eat vegetables, aligning ancient rhythms of nature with the demands of modern agriculture.

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ROLE OF PROBIOTICS IN HEALTH AND EFFICIENCY OF SILKWORMS, APPLICATION METHODS AND BENEFITS

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Introduction

Silkworms are the very sensitive organisms, which cannot resist any small variations in the external environment. They need optimum environmental condition for proper growth and development. like so, the internal environment of the silkworms also play a major role in their processes of metabolism, digestion, respiration, blood circulation, nervous system, internal secretion, muscles, excretion, production of silk, shedding of old cuticle etc. these processes are enhanced by some microorganism called probiotics. Probiotics are live microorganisms that provide health benefits when consumed, generally by improving or restoring the microbiota in the gut. They play an important role in the gut health of the silkworm that is very important for its growth and development. which directly impacts silk production. Probiotics are prepared by selecting specific strains of beneficial bacteria, cultivating them in a nutrient-rich medium, and then concentrating and stabilizing them for use in supplements or food products.

The first discovered probiotic was a certain strain of bacillus in Bulgarian yoghurt, called *Lactobacillus bulgaricus*. The discovery was made in 1905 by Bulgarian physician and microbiologist Stamen Grigorov. The modern-day theory is generally attributed to Russian Nobel Prize laureate Élie Metchnikoff, who postulated around 1907 that yoghurt-consuming Bulgarian peasants lived longer. Same in silkworm, The first probiotic test in silkworms involved identifying the bacterium *Ligilactobacillus salivarius* in the midgut of Eri silkworm larvae. This discovery, made by researchers in Assam, suggests the potential for developing

silkworm are specific probiotics to improve silkworm health and productivity. Some stains of *Bacillus subtilis, Pediococcus pentosaceus, Lactobecillus* spp, Spirulina etc. are currently used as feed supplements to silkworms including *Bombyx mori* to improve the health and efficiency of silkworms. And also some probiotics show antimicrobial property to non-beneficial microbes, disease resistance and immune system modulation. By this all means the silkworms will be healthy, efficient in feed consumption and silk production.

Microbiota Of Silkworm Gut

The silkworm gut naturally hosts a rich probiotic community which is dominated by *Enterococcus, Lactobacillus*, and *Bacillus* spp that supports digestion, immunity, detoxification, growth and development. Gut microorganisms and their role in silkworms as follows

1.Enterococcus spp.

10–30% of microbiota is constituted by *Enterococcus faecalist* microorganism. It helps to enhance the antimicrobial peptides, gut barrier, competitive exclusion of pathogens and immune modulation. It can reduce the infection rate of Nosema bombycis, a microsporidian parasite that causes pebrine disease in silkworms. This protection is due to the production of enterocins, antimicrobial substances that can affect N. bombycis. *E. faecalis* strain YM0831 has been shown to suppress sucrose-induced hyperglycemia in silkworms, suggesting a role in regulating sugar levels.

2.Lactobacillus spp.

Lactobacillus casei, Lactobacillus paraplantarum, Lactobacillus salivarius, and Lactobacillus acidophilus constitute 30-56% of silkworm microbiota. These microorganisms produces lactic acid and synthesises enzymes which helps in digestion of complex carbohydrates and promote better nutrient absorption, leading to improved growth and development of silkworms. this species are known to improve the overall gut health of silkworms by promoting a balanced gut microbiota. This balance helps in preventing the growth of harmful pathogens and strengthens the silkworms' immune system. By improving the overall health and immunity of silkworms, Lactobacillus can indirectly contribute to increased silk production and better cocoon quality. Supplementation with specific Lactobacillus strains has shown potential in reducing mortality rates and enhancing the survival of silkworms when challenged with diseases like those caused by Nosema bombycis.

3.Bacillus spp.

This species micoorganisms are 17-26 % in silkworm gut microbiota. probiotic *Bacillus subtilis* strains can improve silkworm body weight, enhance antioxidant properties, regulate intestinal immunity, and promote B vitamin metabolism. B. subtilis SWL-19 was found to have beneficial effects on silkworm physiology, antioxidant properties, intestinal immunity, and levels of antimicrobial peptides. *Bacillus amyloliquefaciens* This species, along with *Bacillus subtilis*, is known to produce enzymes like alpha amylase and protease. Helps in digestion of carbohydrates and protins. Not all Bacillus spp. Are beneficial, some are pathogenic like *B. thuringiensis* and *B. cereus* they may cause septicimia and toxemia and leads to the death of silkworm larvae.

4.Other beneficial spp.

Weissella, Enterobacter, Acinetobacter, Cyanobacteria, Methylobacteria etc. are minor probiotics present in gut microbiota of silkworms. They helps in detoxification of toxic elements in gut, breakdown of plant polysaccharides, metabolism of plant compounds, and metabolite processing. Directly or indirectly they help health, growth, development and the production of quality silk in silkworms.

External Application Of Probiotics

External application of probiotics to silkworms, specifically via mulberry leaves, can positively impact their health and economic traits. Probiotics, such as Lactobacillus spp, Spirulina, *Pediococcus pentosaceus, Saccharomyces cerevisiae*, can improve silkworm growth, enhance their immune system, and increase their resistance to diseases. These beneficial effects are achieved by modulating the gut microbiota, improving nutrient absorption, and potentially producing antimicrobial substances. Providing treated leaves to silkworms during 3rd–5th instars with a frequency of 1-2 times for 3-4 days in a instar can helps to 8–12% increase in cocoon weight, Longer silk filament (900+ meters) , Higher survival and reduced pathogen load can also be observed by external application of these probiotics.

Methods Of Extenal Applications

1) **Mulberry Leaf Coating**

It is Most common method in which Probiotics (e.g., Bacillus subtilis, Lactobacillus spps, spirulina) are suspended in sterile water and sprayed onto mulberry leaves. The leaves are

then fed to silkworms. It is easy and cost-effective method, Ensures direct ingestion during feeding and Minimizes gut stress from direct dosing.

2) **Leaf Dipping**

This process involves dipping of Fresh mulberry leaves in probiotic solution (1–2% suspension), then air-dried before feeding. It ensures uniform coating and probiotic intake.

3) **Dusting or Powder Application**

Probiotic powder mixed with carrier (like talc powder) is lightly dusted on leaves. It used with Bacillus-based commercial probiotic powders. But it is less efficient method and may cause respiratory problems to both humans and silkworms.

4) **Spraying in Rearing Environment**

Probiotics are sprayed on rearing beds or trays to reduce pathogenic microbes in the environment. It helps to suppress fungal/bacterial load (e.g., Aspergillus, Nosema) in the rearing room. Economic method for application probiotics.

Benefits Of Probiotics In Silkworm

1.Gut Health Improvement

Improving gut health in silkworms through probiotics involves enhancing the microbial balance, boosting digestion, strengthening immunity, and protecting the gut barrier. Probiotics such as *Lactobacillus*, *Bacillus*, and *Saccharomyces* spp. help maintain a balanced gut microbiota. This leads to Better digestion and absorption of nutrients, Reduction in gut infections and Stabilized intestinal pH, promoting enzyme activity.

2.Enhanced Nutrient Utilization

Probiotics can Produce enzymes (e.g., amylase, protease) that break down feed more efficiently, enhance assimilation of proteins, lipids, and carbohydrates and improve the overall feed conversion ratio (FCR) This Result in Faster growth and increased larval weight

3. Increased Disease Resistance

Probiotics stimulate the immune system by Outcompeting pathogenic microbes (compSSSSetitive exclusion), they Produces antimicrobial substances (e.g., bacteriocins) and Enhances the activity of immune-related genes. This reduces the need for antibiotics and lowers mortality rates.

4. Improves Commercial Characters of Cocoon

Probiotics like *Bacillus subtilis*, *Lactobacillus acidophilus*, and *Enterococcus faecalis* help increase cocoon weight, shell weight, shell ratio (percentage of cocoon shell weight to total cocoon weight) In previous studies, probiotic-fed silkworms showed 10–18% higher cocoon weight, 12–25% higher shell ratio and 8–15% longer filament length. Better nutrient absorption and protein synthesis directly support silk gland development and fibroin/sericin production.

5. Increased Haemolymph Protein Content

Probiotics boost systemic metabolism and protein levels in haemolymph. This supports silk gland function and fibroin synthesis. Haemolymph protein was 18–28% higher in probiotic treated silkworms in several studies. Which helps in activation of immune system, nutrient and hormone transport and moulting process.

5. Other Benefits of Prob

In several experiments, probiotics supplemented in mulberry leaves or artificial diets have resulted in shorter larval duration, Increased pupation rate, better survival percentages and reduces mortality rate by preventing diseases and promoting healthy growth. Probiotics can help silkworms cope with stress by regulating their physiological responses and promoting a healthy gut-brain axis.

Conclusion

Probiotics play a vital role in enhancing the overall health and biological efficiency of silkworms. By improving gut microbiota balance, probiotics support better digestion, nutrient assimilation, and metabolic activity, leading to accelerated growth and development. Additionally, their immunomodulatory effects strengthen disease resistance, reducing mortality and the need for chemical interventions. Various application methods including mulberry leaf coating, leaf dipping, powder form applications, supplementation in artificial diets, and direct gut inoculation have proven effective in establishing beneficial microbial populations within the silkworm gut. The result is a marked improvement in cocoon quality, silk yield, and economic return for sericulture. Thus, integrating probiotics into silkworm rearing practices offers a sustainable and biologically safe approach to improving productivity and maintaining silkworm health. ultimately supporting the sustainability and profitability of sericulture. As research advances, the integration of targeted probiotic strains into routine silkworm rearing practices

holds the potential to transform the industry by promoting eco-friendly and biologically driven solutions to current challenges.

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DEVELOPMENTAL CHANGES DURING SENESCENCE AND ABSCISSION

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Abstract

Senescence and abscission represent key physiological processes in plant development that contribute to organ separation and eventual plant aging. These processes are characterized by complex biochemical and molecular mechanisms involving metabolic decline, hormonal regulation, and environmental responses. Senescence may occur in whole plants or in specific organs and is closely linked to programmed cell death. Abscission, on the other hand, enables detachment of organs such as leaves, flowers, and fruits through well-defined abscission zones regulated by hormonal crosstalk. This article reviews the developmental changes, mechanisms, regulatory pathways, and recent biotechnological advances for manipulating senescence and abscission, with emphasis on improving crop yield and mechanical harvesting efficiency.

Keywords

Senescence, Abscission zone, Ethylene, Auxin, Programmed cell death, Mechanical harvesting

Introduction

Senescence and abscission are vital developmental processes in the plant lifecycle, ensuring efficient resource redistribution and facilitating reproductive success. Senescence is marked by a progressive decline in cellular activity and metabolic functions, ultimately resulting in organ death. Abscission is the detachment of organs through the activation of abscission zones (AZs), involving tightly regulated hormonal and molecular changes. Understanding these

processes at the developmental, cellular, and genetic levels is crucial for enhancing crop productivity and minimizing postharvest losses.

Contents

Types of Senescence: Leopold (1961) categorized senescence into four types:

- Overall senescence: Observed in annuals like soybean and wheat; affects the entire plant after reproduction.
- Top senescence: Shoots perish while roots remain viable (e.g., dock, perennial herbs).
- Deciduous senescence: Leaf loss in deciduous trees; stem and roots survive.
- Gradual senescence: Sequential aging from lower to upper leaves, as seen in coconut.

Cellular Mechanisms of Senescence:

Senescence involves irreversible metabolic shifts, primarily catabolic, including degradation of macromolecules:

- Carbohydrates are metabolized to support respiration via TCA cycle.
- Proteins are broken into amino acids aiding nitrogen transport.
- Lipids are converted to Acetyl-CoA for energy.
- Nucleic acids are degraded to provide nucleotides for other biosynthetic pathways.

Cellular senescence halts cell division and triggers resistance to apoptosis, primarily through p53 pathways and BCL-2 proteins. Recent research also indicates that senescence may be reversible under certain epigenetic influences.

Developmental and Molecular Basis of Abscission:

Abscission occurs in specialized AZs, regulated by hormonal signaling:

- Ethylene: Accelerates abscission by promoting enzyme activity.
- Auxin: Maintains AZ integrity; a decrease in auxin facilitates abscission.
- Jasmonic acid: Enhances abscission under stress.
- Regulatory genes: KNAT, AS1/AS2, BOP1/2, and transcription factors such as MADS-box genes (MC, J, J2).

In Arabidopsis, abscission involves MAP kinase cascades (MPK3/6), receptor-like kinases (HAE/HSL2), and downstream transcriptional changes. In Solanum lycopersicum (tomato), MADS-box genes regulate AZ development.

Manipulation of Abscission:

Control of abscission is critical for yield and postharvest quality:

- Hexanal reduces ethylene biosynthesis, preventing fruit drop.
- Nano-calcium application strengthens cell walls and delays AZ activation in grapes.
- Chitosan and NDGA inhibit cell wall-degrading enzymes.
- Tomato mutants (J, J-2, MC) lack AZs, enabling mechanical harvesting.
- Pepper landrace UCD-14 facilitates easy destemming through QTL-regulated AZ activity.
- Brassica napus gene editing (BnMAN7A07, BnaIDA) delays silique dehiscence.

Conclusion

Senescence and abscission are essential for the developmental and reproductive success of plants. Recent advances in molecular biology and biotechnology provide promising tools for regulating these processes, enabling improved crop yield, reduced postharvest losses, and labor efficiency in harvesting. Understanding these biological systems offers future avenues for genetic improvement and precision agriculture.

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CASTOR AS A BORDER CROP FOR COTTON AND MAIZE IN MANGALUR BLOCK, CUDDALORE DISTRICT – A SUCCESS STORY

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Introduction

Situation analysis/Problem statement in Mangalur block, Cuddalore district

- Wild boar problem is prevailing in rainfed crops of mangalur block of cuddalore district
- Castor is suggested as an alternative crop for rainfed condition
- Since, Cotton and Maize requires more labour and care, this crop castor can be tried with better profit and least care.

Implementation of the demonstration

10 demonstrations were made on castor as a main crop and border crop in cuddalore district. The village sirupakkam was chosen in Nallur block and seeds were distributed to 10 beneficiaries. Sowing was taken during kharif '2024.Farmer were instructed to go for main crop out of 10 farmers 7 of them has taken sown as border crop as there is lesser rainfall for sowing. All the recommended practices were given as training to the beneficiaries of Sirupakkam. Crop vigour was good but there is monkey damage at spike formation stage in one farmer field and crop was was destructed at this stage.

Output

- Yield obtained by the farmer is 1468 kg/ha with a benefit cost ratio of 1.89
- As border crop it performs good and only sowing cost was included hence a good benefit cost ratio was obtained as border crop

But for 7-8 month crop duration Main crop recorded a higher gross return Rs. 85,422 hence this can be recommended as one of the profitable rainfed crop for cuddalore district. Besides the prevailing cropping pattern this can be recommended as an alternative crop for this region and helps for crop rotation and breaking of insects and diseases in continuous mono cropping condition (Maize is severely infested with fall army which is the major crop under rainfed in Sirupakkam).



Results of the demonstration

Hybrid	Grain yield kg/ha	Gross return Rs./ha	Net return Rs./ha	B:C
Border crop	100	5819	3819	5.82
Main crop	1468	85422	40,422	1.89

Conclusion

Farmers around the village were satisfied with the performance of the castor hybrid. All are willing to raise as border crop. Farmers were trained on the production technologies of castor and emphasized the success of the crop as main crop. As a impact of this study the farmers of Nallur block is willing to go for castor hybrid as the border crop in cotton and maize.

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QUALITY PARAMETERS OF CHEWING CANE

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Introduction

In Agriculture sector, sugarcane share is about 7% of total agriculture production and occupied 2.6% of India's gross cropped area with functioning of 527 sugar factories. India occupies an important place among the sugarcane producing country and has a neck to neck race with Brazil. Sugarcane is cultivated in an area of 4.44 mha in India with the annual production of 306.07 lakh tonnes and cane productivity of around 69.0 t/ha with an average sugar recovery of approximately 10%.

Sugarcane (*Saccharum officinarum*) is one of the major tropical C_4 plant crops which is cultivated in the tropical and subtropical regions globally and contributes to 70 per cent of the world's sugar. Agro-climatic conditions influence the crop growth and development. A mean temperature of 28 to 32 ^{0}C is best suited for the growth of sugarcane. Temperature above 50 ^{0}C arrests its growth, whereas temperature below 20 ^{0}C will slow down the growth. Relative humidity of 70 to 85 per cent during growth and 55 to 75 per cent during ripening phase is ideal. Relative humidity less than 50 per cent during growing season is not suitable for sugarcane cultivation.

Over five million farmers are involved in the cultivation of sugarcane in tropical and subtropical India, the two distinct agroclimatic regions of the crop in the country. Sugarcane in India is cultivated broadly under two distinct agro-climatic conditions commonly referred to as tropical and subtropical belts. The tropical belt comprising Maharashtra, Tamil Nadu, Karnataka, Andhra Pradesh, Gujarat, Chhattisgarh, Odisha and Kerala accounts for 42.9% of the total area

under sugarcane cultivation in the country. The sub-tropical sugarcane region constitutes around 57.1% of total cane area in the country. The Uttar Pradesh, Bihar Punjab, Haryana, Uttarakhand, parts of Madhya Pradesh, Rajasthan, West Bengal, Jharkhand, Assam, and other north and north-eastern states fall in sub-tropical belt.

There are two types of cane grown in India one is for Crushing sugar commonly known as mill cane and another is chewing cane harvested during January for celebrating pongal. Normally the risk on cultivating chewing cane in good soils is lesser when compared to mill cane. Insects like early shoot borer and internode borers are effectively managed and was comparatively lesser in chewing cane. The yield is on par in both types of cane cultivated. But the chewing cane is not crushed for sugar production; when there is glut in the market of chewing cane and as well as under normal conditions this can be tried for sugar production since the varieties performance and resistance to the insect and disease are good.

Cane type	Brix	Polarity (%)	Purity (%)	Commercial cane sugar (CCS%)
Chewing cane				
1.	19.64	17.393	88.560	12.041
2.	20.16	18.009	89.331	12.602
Crushing /Mill Cane COC13339	18.65	17.630	94.730	12.580

Conclusion

Considering this, the quality parameters of chewing cane was analysed at Lab and found that good. It is the decision of the sugar mills to crush chewing cane also for sugar production. The demand for sugar production and ethanol is increasing day by day hence this alternate avenue can be checked by the sugar mills for further action in future.

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DEMONSTRATION OF AMARANTHUS PLR 2 WITH FARMERS PARTICIPATION IN CUDDALORE DISTRICT - A SUCCESS STORY

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Introduction

Amaranthus PLR 2 was released during 2024 by the Vegetable Research Station, Palur. It yielded 43t/ha White stemmed rich in βcarotenoides 8 mg/100g. Hence for wider popularization in cuddalore distrct, this variety was demonstrated in Vridhachalam, Vallampadugai and Mel bhuvanagiri of cuddalore district in 10 locations. The result is as follows.

Out come

Crop	Plot size	Income /plot Rs	Total number of plots	Gross income Rs./acre	Net return Rs./acre	Total cost of cultivation Rs./acre	B:C
White amaranthus PLR2	60 m^2	200	66	13,200	9200	4000	3.3

Mean data of the 10 trials conducted at the farmers' field.

One kg seed is recommended per acre and this was given on free of cost for demonstration purpose. Farmer has taken staggered sowing in 3 months. The vigour was better than the local variety and farmers got an income of around Rs. 6000 per month hence this

introduction improves the livelihood security of the small and marginal farmers. There was no insect and disease infection in farmers' field and raised free of insecticides.





Output

- Crop vigour is good
- Germination was good
- No consumer preference for white stemmed amaranthus resulted in lesser market price than the prevailing variety
- No insects and disease incidence

The constraints on less preference due to white stemmed was clarified by delivering the β carotenoides 8 mg/100g content in PLR2 Amaranthus

Present status of the farmers in using the variety Amaranthus PLR 2

- The beneficiaries are very much interested on Amranthus PLR2. It gives a net income of Rs. 9200/ acre with better benefit cost ratio as there is no money spent on plant protection chemicals and fertilizers. Under organically it was grown and got better market price.

Socio economic impact

- As the net return is more due to enhanced marketable price for the Amaranthus PLR2, the farmers wish to go for cultivating the variety and the same is recommended for large scale adoption.
- The farmers visualised the performance of the Amaranthus PLR 2 throughout the season with their active participation.
- The participation of the farmers in various domains shows positive impact on acceptance of the variety.

Participation of the farmers in various domains

Domain	Bed preparation	Sowing of the seeds	Irrigation & pest scouting	Harvesting
Level of participation	40%	60%	60%	100%

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ROLE OF ENZYME ASSAYS IN PLANT PHYSIOLOGY RESEARCH

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Abstract

Enzyme assays are essential analytical tools in plant physiology, enabling precise measurement of enzyme activities involved in key biological processes such as photosynthesis, respiration, nutrient assimilation, stress responses, and hormone signaling. These assays provide a functional snapshot of plant metabolism under diverse physiological and environmental conditions. By evaluating enzymes like Rubisco, nitrate reductase, superoxide dismutase, and amylase, researchers can understand plant responses to agrochemical treatments, genotypic variations, and environmental stresses. Enzyme assays also play a vital role in assessing the effectiveness of fertilizers, biostimulants, and nanomaterials on plant growth and health. Applications range from screening stress-tolerant genotypes to monitoring developmental changes and validating gene functions in transgenic plants. With advancements in high-throughput techniques and integration with omics platforms, enzyme assays offer a powerful approach to linking molecular insights with physiological outcomes. Their continued use is crucial for enhancing crop performance, resilience, and sustainability in the face of global agricultural challenges.

1. Introduction to Enzyme assays in Plant Science

Enzymes are biological catalysts that govern nearly all physiological processes in plants, from metabolism and growth to stress responses and signaling. Enzyme assays are analytical techniques used to measure the activity of specific enzymes in biological samples. These assays provide a quantitative understanding of how metabolic pathways are regulated, activated, or inhibited under various physiological and environmental conditions. In plant physiology

research, enzyme assays offer a window into the real-time functional status of key biochemical pathways, making them indispensable tools for studying plant development, nutrient assimilation, stress adaptation, and more.

2. Principles and Types of Enzyme Assays

2.1 Basic Principle

Enzyme assays work by monitoring the rate at which a substrate is converted into a product. This transformation is often linked to a measurable change such as color intensity, absorbance, fluorescence, or pH. The rate of change directly correlates with the enzyme's activity.

2.2 Types of Enzyme Assays

Spectrophotometric Assays; that measure absorbance at specific wavelengths (e.g., NADH/NAD^+ at 340 nm); Colorimetric Assays use colour changes due to product formation (e.g., dinitrosalicylic acid for amylase); Fluorometric Assays detect enzymatic products that fluoresce under specific light and Coupled Assays use a secondary enzyme to generate a measurable product.

2.3 Continuous vs Discontinuous Assays

Continuous assays track changes in real-time. Discontinuous assays stop the reaction at and intervals to analyze the products.

3. Scientific Overview: Role of Enzyme Assays in Plant Physiology Research

Enzyme assays are essential analytical tools used to measure the activity of specific enzymes under defined conditions. In plant physiology, these assays help elucidate the biochemical basis of physiological processes, such as photosynthesis, respiration, nitrogen metabolism, stress responses, and hormone signaling.

3.1 Understanding Metabolic Pathways

Enzyme assays allow quantification of enzyme activities involved in primary and secondary metabolism (e.g., Rubisco in photosynthesis, nitrate reductase in nitrogen assimilation, or peroxidases in ROS detoxification). This helps map out metabolic fluxes and identify rate-limiting steps in biosynthetic or catabolic pathways.

3. 2 Studying Plant Responses to Stress

Enzymes such as superoxide dismutase (SOD), catalase (CAT), ascorbate peroxidase (APX), and others are key indicators of oxidative stress. Their activity levels reflect how plants

respond to abiotic (e.g., drought, salinity, temperature) and biotic (e.g., pathogen attack) stresses. Enzyme assays thus help to assess stress tolerance and adaptation mechanisms of plants under various biotic and abiotic stress and in evaluation of various kind of soil and seed treatments in plants such as nanofertilizer, nanopesticide and many agrochemicals.

3.3 Evaluating Photosynthetic Efficiency

Enzymes like Rubisco (ribulose-1,5-bisphosphate carboxylase/oxygenase), carbonic anhydrase, and enzymes of the Calvin-Benson cycle are studied to assess carbon fixation efficiency. Changes in their activity can indicate shifts in photosynthetic performance under varying agrochemical treatments and environmental conditions.

3.4 Hormonal and Signaling Studies

Enzyme assays are used to track biosynthetic enzymes involved in the synthesis of phytohormones (e.g., ACC synthase for ethylene, GA oxidase for gibberellins). These help understand hormone regulation and signal transduction, especially during developmental stages or in response to external stimuli.

3.5 Functional Genomics and Transgenic Research

Enzyme activity serves as a biochemical phenotype in transgenic or mutant lines. Overexpression or silencing of genes encoding specific enzymes is often confirmed through enzyme activity assays, validating gene function in physiological contexts.

3.6 Quantitative and Diagnostic Tool

Many enzyme assays (e.g., NADH-coupled assays, spectrophotometric or fluorometric assays) provide rapid and sensitive quantification. These are indispensable in high-throughput screening for breeding programs, stress tolerance evaluation, and physiological diagnostics.

3.7 Evaluation of Nutrient Assimilation

Enzyme assays are essential for evaluating the biochemical impact of agrochemical treatments on nutrient assimilation in plants. Enzymes such as nitrate reductase, glutamine synthetase, acid and alkaline phosphatases, proteases, and amylases serve as functional markers of nutrient metabolism. Under varying doses of fertilizers, micronutrients, or plant growth regulators, changes in these enzyme activities provide insights into the plant's capacity to uptake, convert, and mobilize nutrients. For example, enhanced nitrate reductase activity signifies improved nitrogen assimilation, while elevated protease activity under nutrient stress or hormonal treatment indicates active nitrogen remobilization through protein degradation.

Similarly, amylase activity reflects the breakdown of starch into sugars, facilitating energy availability during nutrient assimilation and growth. Monitoring these enzymatic responses allows researchers to assess the efficiency of agrochemical applications, tailor input strategies, and support sustainable and nutrient-efficient agricultural practices.

4. Applications in Experimental Plant Physiology

4.1 Screening Genotypes for Stress Tolerance

Enzyme assays are frequently used in plant breeding and physiology to screen varieties for tolerance to drought, salinity, or nutrient deficiency. High activity of enzymes like SOD or nitrate reductase is often associated with better adaptability and productivity under sub-optimal conditions.

4.2 Evaluating Agrochemical Treatments

The biochemical effects of fertilizers, growth regulators, biostimulants, or pesticides can be evaluated through enzyme assays. Changes in enzyme activity serve as early indicators of physiological alterations or improvements before visible symptoms appear.

4.3 Monitoring Growth and Development

Plant development stages—like seed germination, leaf expansion, or senescence—are associated with shifts in enzyme activities. For example, increased amylase activity in germinating seeds indicates active starch hydrolysis for energy mobilization.

5. Conclusion and Future Prospects

Enzyme assays serve as indispensable tools in plant physiology, enabling precise evaluation of metabolic and stress-responsive pathways at the biochemical level. By quantifying the activity of key enzymes involved in photosynthesis, respiration, antioxidative defense and nutrient assimilation, these assays provide critical insights into plant function, adaptation, and health. Their significance in research spans from basic metabolic profiling to applied fields like crop improvement, stress physiology, and sustainable agriculture. Their application not only deepens our understanding of plant responses to environmental cues but also guides the development of strategies for crop improvement, stress resilience, and sustainable agriculture. As technology advances, high-throughput enzyme assay platforms, miniaturized kits, and integration with omics tools will further enhance our ability to explore plant biochemistry at scale. Ultimately, enzyme assays will remain central to understanding and manipulating plant function in a changing climate and growing global demand for resilient crops.

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HUGE SEEDS PRODUCED BUT NONE GERMINATE UNDERNEATH IN TWO MAJOR TREE SPECIES; HUMAN INTERVENTION AND BIRDS PLAY A MAJOR ROLE FOR THEIR SPREAD

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Introduction

I have observed the well grown trees of *Terminalia catappa* and camel foot tree (*Bauhinia virgata*) which are producing numerous seeds in my office premises for four years. *Terminalia catappa, Terminalia catappa* L., commonly known as Indian Almond, belongs to the Combretaceae family. The generic name comes from the Latin 'terminalis' (ending) which refers to the habit of the leaves being crowded at the ends of the branches This is a large, spreading type of tree and usually grows in tropical environments and coastal communities It provides edible nuts and wide range of services including avenue, shade, and ornamental trees along sandy seashores. Tropical almond is an underutilized fruit which is rich in antioxidants, vitamins, and pigments. Its fruits are eaten especially by humans, birds and animals. The global production of its fruit/seed is estimated at 700,000 tons/year. Kernel yield is estimated to be about 5kg/tree/year. The timber of the tree is medium density with normal strength and elasticity and rupture but strong in shear strength. It is used as herbal medicine for treating various ailments like liver and intestine infections, and other related diseases. Despite numerous potentials and uses, the tree is not fully appreciated nor utilized as a multipurpose tree (MPT). Similar to other Terminalia species, T. catappa seeds and other economic products are collected from wild or naturally occurring trees. There are few reports of commercial-level plantations on this species or other Terminalia species such as T. arjuna or T. bellerica. This can be attributed to various reasons including the lack of awareness, lack of post-harvesting techniques, market linkage and value chain, etc. It can be called an untapped or underutilized tree .There is a potential to

promote this species for various purposes including the enhancement of the green cover in urban areas where it is not found prominently. This review aims to explore the potential of T. catappa – a multipurpose tree species.

The native range of the tree is largely restricted to tropical areas of the Asia-Pacific region including Comoros, Madagascar, North Australia, Cambodia, India, Japan, Laos, Malaysia, Thailand, and Vietnam. It was introduced in several regions including Central and South America, West and Central Africa, and Caribbean islands. The tree is well adapted to well-drained, aerated, sandy and rocky coastal habitats and grows in an elevational range of 0–800m . Soil pH suitable for the growth of trees is usually neutral to moderately alkaline and rich in bases. However, it can be grown in strongly acidic soils. Good drainage is required on clay soils. T. catappa has a strong tolerance to moderate to high salinity in the root zone. The best tree growth is observed in regions with a mean annual temperature of 15–35 ◦C and mean annual rainfall between 750 and 3000 mm. Trees growing solitary in an open area produce more seeds than trees grown in shaded areas . Seawater salinity on T. catappa and reported that exposure did not alter the macronutrient contents in the tree. The tree can protect itself from seawater salinity through the compartmentalization of sodium salts in the pericarp of the fruit. The DBH (diameter at breast height), increment rate reported for this species in Vanuatu is 2–3 cm/year. It is also a drought-tolerant tree species and their seedlings are adapted to heat stress. The seeds remain viable for more than 4–5 months and germinate readily but mass vegetative propagation by rooted cuttings has also been reported but not widely adopted. In India, entire fruits of T. catappa are planted fresh in July in nurseries and the germination rate is about 25–50 % . The seedlings should be planted in the field during the monsoon.

I have observed the tree of more than 20 years aged old tree. Almost flowering and seed production done throughout the year and the number of fruits/seeds produced is larger in number. From lakhs of fruits produced and fall on the ground none of the fruit germinate as a tree seedling under the tree even with a good rainfall. Hence we can conclude that this tree grown or forest is made by birds and human intervention.

Promoting vegetative propagation of T. catappa is critical for upscaling this species in agroforestry and avenue plantations whilst carrying out tree breeding and improvement works including genomics. The supply of QPM to different stakeholders would encourage this species

at various landscapes such as farmlands, streets, roads, institutional areas, parks, cultural sites and historical monuments.

Bauhinia variegate

Bauhinia variegata is a small to medium-sized deciduous tree with a short bole and spreading crown, attaining a height of up to 15 m and diameter of 50 cm. In dry forests, the size is much smaller. The bark is light brownish grey, smooth to slightly fissured and scaly. Inner bark is pinkish, fibrous and bitter. The twigs are slender, zigzag; when young, light green, slightly hairy, and angled, becoming brownish grey. Leaves have minute stipules 1-2 mm, early caducous; petiole puberulous to glabrous, 3-4 cm; lamina broadly ovate to circular, often broader than long, 6-16 cm diameter; 11-13 nerved; tips of lobes broadly rounded, base cordate; upper surface glabrous, lower glaucous but glabrous when fully grown. Flower clusters (racemes) are unbranched at ends of twigs. The few flowers have short, stout stalks and a stalklike, green, narrow basal tube (hypanthium). The light green, fairly hairy calyx forms a pointed 5-angled bud and splits open on 1 side, remaining attached; petals 5, slightly unequal, wavy margined and narrowed to the base; 5 curved stamens; very slender, stalked, curved pistil, with narrow, green, 1-celled ovary, style and dot like stigma. Pods dehiscent, strap-shaped, obliquely striate, 20-30 by 2-25 cm; long, hard, flat with 10-15 seeds in each; seeds brown, flat, nearly circular with **coriaceus testa**

In its natural habitat in India, the tree is deciduous, remaining leafless from Jan-Feb to April with leaf fall in Nov-Dec. Flowering occurs when the plant is leafless. Tree starts flowering at a very early age of 2-3 years. The seeds disperse from the pods and germinate on sites with favourable light and moisture conditions, while in unfavourable niches the radicle dries up or is destroyed by birds

Conclusion

A huge number of pods are produced by camel foot tree which is not Tall and good girth in nature. The seeds are shattered nearby the tree while closely watching it was observed that none of the seeds germinate under the tree. All the seeds (approximately 5000 seeds) in a single camel foot tree are wasted. Hence in dispersion of the tree and especially self seeding birds and winds plays a pivotal role on natural spread of the tree or otherwise human should be involved in planting the tree and propagate the tree. By nature it is very week in germination.

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NADEP COMPOST

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Introduction

Composting began a comeback toward end of the last century with interest surging in recent years as economic and environmental factors have begun to change the way the world looks at crop production, environmental concerns chemical agriculture raises, and waste society generates. Compost is a way of returning safe, easily mineralised, organic matter, or humus, to the soil. Even though organic matter is a relatively small fraction of soil content, it can have a dynamic influence on the health of the soil as a whole. Compost is organic matter that has been broken down through the action of aerobic microbes and the heat they produce then subsequently built up into humus.

NADEP Method of Composting :

NADEP method of making miracle compost was first invented by a farmer named Narayan Deotao Pandharipande (also popularly known as “Nadepkaka”) living in Maharashtra (India). This method becomes quite popular among the farmers in western India. In dryland conditions, organic manures play a great role as they not only supply balanced nutrients but also retain substantial amount of moisture. Traditionally, farmers used to apply farmyard manures to crops grown under rainfed condition. No scientific procedures are followed for preparing the manure and as a result the quality of the manure used to be very poor.

Selection and Preparation of Site for NADEP Tank :

NADEP method uses a permanently built tank of mud or clay bricks, or cement blockettes. It is, therefore, important to choose the permanent site for the tank with care. This is good anytime of

the year where moisture is limiting, and is the best way to make compost after the rains have finished and during dry season. Prepare and dig the pit, or better still, a series of three pits, when land is moist and easier to dig, and/or when there is a gap between other farming activities.

• If possible, make compost immediately at the end of the rainy season while there are plenty of green and moist plant materials.

• In the dry season, make the pit near a place where water can be added, e.g. next to the home compound where waste water and urine can be thrown on the compost materials, or near a water point, e.g. a pond, or near a stream where animals come to drink.

• Mark place of the pit with a ring of stones or a small fence so people and animals do not fall into it accidentally.

Construction of NADEP Tank :

1. The inside dimensions of the tank are as follows:

Length: 3 metres , Width: 2 metres

Height: 1 metre

2. This size of tank requires 120–150 blockettes or mud bricks, four 50-kg bags of cement, and two boxes of sand. Five iron rods can be used to strengthen the floor, but they are not essential.

3. The building should be done by a properly qualified mason, i.e. someone who knows how to build such a structure.

4. The floor of the tank is made of bricks or blockettes laid on the ground and covered with a layer of cement.

5. Each of the four walls has three rows of holes or gaps between the bricks or blockettes, as shown in Figure.

6. After the tank is built, the walls and floor are covered with a light plaster of fresh cow dung mixed with water and then the plaster is allowed to dry.

Filling the Tank :

NADEP tank is filled in one or two days of hard work. It has to be done by a team. Before filling the tank, the following materials must be collected together:

1. Dry and green plant materials: 1400–1500 kg is needed. Grass, hay or straw that has left over from feeding animals, or that has been damaged by rain, is very suitable.

2. Cow dung or partly dried bio slurry (the discharge from a biogas digester): 90–100 kg

3. Dried soil that has been collected from cattle pens, cleaning drains, paths, etc.: 1750 kg are needed. The soil should be sieved to remove old tins, plastic, glass, stones, etc.

4. Water: amount varies with the season and the proportion of dry to green plant materials available. However, usually an equivalent amount to plant materials is needed, i.e. 140–150 litres.

5. If urine from cattle and/or people is available, it should be diluted in the proportion of 1 part urine for 10 parts water (1 jug of urine put into 10 jugs of water in a bucket).

6. Before starting to fill the tank, sides and floor of the tank are thoroughly wetted with slurry made from fresh cow dung mixed into water. 7. The three layers used to fill the tank are as follows:

First layer: use 100–150 kg of dry or mixed dry and green plant materials to make a layer 15–25 cm thick at the sides, and slightly thicker in the middle.

Second layer: mix 4 kg of cow dung or 10 kg of fresh biogas slurry in 25–50 litres of water and sprinkle or scatter it over the plant materials so they get completely moistened.

Third layer: cover the wet plant waste and cow dung or slurry layer with 50–60 kg of clean, sieved top soil.

8. Continue to fill the tank like a sandwich with these three layers put in sequence. Put more materials in the middle of the tank than around the sides. This will give a dome shape to the filled tank with the centre 30–50 cm higher than the sides.

9. Cover the last layer of plant materials with a layer of soil 7–8 cm thick. Make a cow dung plaster and cover the soil so that there are no cracks showing. The top of the filled tank can also be covered with plastic, particularly to protect the compost making process during rainy seasons.

10. After the tank is filled, the progress of compost making can be tested by pushing a stick into thetank through the gaps in the wall. In a school or agricultural college, the students can monitor the changes in temperature by inserting a long thermometer, e.g. a soil thermometer.

11. As the materials decompose in the compost making process, the top of the filled tank will shrink down below the sides of the tank.

NADEP Compost Making Process :

It is important to keep the contents of the tank moist, i.e. with a moisture content of 15–20%.

1. Check the mud plaster seal on the top of the tank and fill any cracks that appear with cow dung plaster.

2. Pull out any weeds if they start to grow on the surface, as their root systems can damage the coverand take water out of the compost.

3. If the atmosphere gets very dry and hot, such as in the dry season, water can be sprayed through the gaps in the walls of the tank.

Maturity and harvesting :

The decomposition process for compost to be made takes about three to four months in a warm climate. When it is mature, it is dark brown, moist, and with a pleasant earthy smell: little canbe seen of the original materials that were put into the tank. This mature compost should not be allowed to dry out or it will lose a lot of its nitrogen. However, before the compost is mixed to makenursery soil, it should be sieved. The sieved compost is used in making the soil for the nursery beds,and the remainder is kept and added to a new compost-making process. One NADEP tank of the size described here can produce about 300 tonnes of high quality compost.

Unit Cost :

The cost of construction of the tank with brickwork in cement morter and light thatched roof has been estimated at Rs.4100/- per unit and the operational cost has been estimated at Rs.950/- per cycle per plant

Production from one unit:

About 3 t of compost is generated per tank per cycle. In the first year 2 cycle and from the 2nd years onward 3 cycles can be produced. Thus, each tank can produce 6 t in the first year and 9 t from the 2nd year onwards.

Unit Size :

It is necessary that a farmer should have at least 2 tanks so that when one is filled up the other one is available for loading the material generated in his farm. Thus, for a farm size of 5 acres dryland a unit of two tanks is needed. If the farmer is having mixed farm of dry land and irrigated farm, one should have 4 tanks. Hence, the following unit costs are suggested.

Characteristics of Good Compost:

Although the quality of compost is best evaluated through the growth and productivity of the plants grown on soil treated with it, it is possible to evaluate compost quality through seeing, touching andsmelling:

• Good quality compost is rich in plant nutrients and has a crumb-like structure, like broken up bread.

• It is black or dark brown and easily holds moisture, i.e. water stays in it, and it does not dry out fast. It has a good smell, like clean newly-ploughed soil, with a smell somewhat like that of lime or lemon.

Benefits :

• Reduced cash expenses on chemical fertilizer, improved soil fertility, increased yield

• Supports organic crop production, reduced dependence on outside inputs

• From each NADEP tank approximately 2.5 tons of compost is prepared within 90-120 days.

• The use of compost reduced the need for mineral fertilizer thus reducing production costs and outside dependence.

Problems in Using Compost :

• The product is weighty and bulky, making it expensive to transport.

• The nutrient value of compost is low compared with that of chemical fertilizers, and the rate of nutrient release is slow so that it cannot usually meet the nutrient requirement of crops in a short time, thus resulting in some nutrient deficiency

• The nutrient composition of compost is highly variable compared to chemical fertilizers.

• Agricultural users might have concerns regarding potential levels of heavy metals and other possible contaminants in compost, particularly mixed municipal solid wastes. The potential for contamination becomes an important issue when compost is used on food crops.

• Long-term and/or heavy application of composts to agricultural soils has been found to result in salt, nutrient, or heavy metal accumulation and may adversely affect plant growth, soil organisms, water quality, and animal and human health

Conclusion

Compost has been considered as a valuable soil amendment for centuries. Most people are aware that using composts is an effective way to increase healthy plant production, help save money, reduce the use of chemical fertilizers, and conserve natural resources. Compost provides a stable organic matter that improves the physical, chemical, and biological properties of soils, thereby enhancing soil quality and crop production as well as farm productivity on sustainable basis.

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RESPIRATION AND THEIR REGULATION METHODS IN FRUITS AND VEGETABLES

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Introduction

A continuous supply of energy is essential for each and every living organism. The energy is required to perform various necessary biochemical functions like maintenance of cellular organization, membrane permeability, transportation of metabolites etc. Respiration is defined as the process by which cells release energy from organic compounds to generate ATP through a series of chemical reactions involving the transfer of electrons and these ATP molecules act as energy resource for cell. A reduction in respiration cause decreased ATP production and consequently lesser energy is available for carrying biochemical processes associated with ripening, resulting in quality changes. Respiration is considered as a programmed continuation of both catabolic and anabolic processes. This process occurs in mitochondrion of the cell.

There are mainly two types of respiration: aerobic respiration and anaerobic respiration, depending upon availability of oxygen. In aerobic respiration, oxygen (O2) is the final electron acceptor while in anaerobic respiration, or fermentation, some other compound is the final electron acceptor.

Aerobic respiration

Aerobic respiration is the major biochemical process supplying energy. It involves the oxidation of certain organic compounds i.e. glucose, maleic acid, stored in the tissues. The compounds that are oxidised during this process are known as respiratory substrates. Aerobic respiration occurs in three phases: glycolysis or Embden-Meyerhoff-Parnas (EMP) pathway, the

Krebs or Tri-carboxylic acid cycle and the electron transport chain. In glycolysis, a molecule of the six-carbon sugar glucose is oxidized to two molecules of the three-carbon pyruvate. The Krebs cycle completes the oxidation of pyruvate to produce carbon dioxide (CO2) and reduced electron carriers. In the electron transport chain, a proton (H+) gradient drives the production of even more ATP and is coupled with the transfer of electrons to oxygen (O2), producing water (H2O). After the entire process of respiration is complete, much of the energy released from the glucose is recaptured in the production of ATP.

Glucose is the most favoured substrate for respiration. All carbohydrates other than glucose are converted into glucose first before they are used for respiration. Fats are metabolized into glycerol and fatty acids first and then to acetyl CoA and glyceraldehyde-3- phosphate, respectively. Proteins are degraded individual amino acids (after deamination) and then enter the respiratory pathway. The respiration is exothermic in nature and theoretically, 60% of the bond energy is lost as heat. However, calorimetry studies have shown that respiration in postharvest tissues often results in even more dissipation of energy as heat loss (90% or more) and less ATP synthesis. This heat contributes to an increase in the temperature of the commodity and is known as vital heat or heat of respiration. Heat of respiration is a primary consideration in designing the storage for horticultural crops.

Anaerobic respiration

Aerobic respiration is preferred energy producing pathway in fruits and vegetables. But under the limiting O2 conditions, fermentation becomes increasingly important. During this process, pyruvic acid produced during the glycolysis is converted to lactic acid, ethanol or acetaldehyde. Increase in fermentation helps the cell meet its ATP requirement under anaerobic conditions. Anaerobic respiration produces much less energy than aerobic pathway and elevated CO2 concentrations have deteriorative effect on the product quality. Anoxia results in injuries to tissue. High concentrations of fermentative metabolites are also associated with various physiological disorders like necrosis, discoloured tissues, offflavours, off-odours etc. The oxygen concentration at which anaerobic respiration starts is called extinction point. It varies between the tissue types and also species, cultivar, development stage, maturity etc.

Apart from aforementioned respiratory processes, two other forms, alternative and residual respiratory processes are also found.

Alternative respiration is an alternative pathway to cytochrome pathway of electron transport to O2. This exothermic process results in production of CO2 but no ATP generation occurs because the electron transfer chain is not coupled to oxidative phosphorylation. This respiration occurs when cytoplasm respiration is blocked. It is also known as thermogenic respiration or cyanide insensitive respiration. Alternative respiration causes a rapid loss of storage polysaccharides, electron transport without the loss of reducing power, and generation of heat. The alternate system has been found responsible for increasing the internal temperature of ripening mangoes by 10°C.

Another type of respiration is residual respiration. The enzymes like polyphenol oxidase and peroxidase are involved in wound repair and in defence mechanism against intruding micro-organisms. The consumption of O2 by these processes, results in what is called as residual respiration. The browning of fruits and vegetable is essentially a wound repairing phenomenon carried out by PPO. In damaged/peeled/cut/sliced produce, level of tissue metabolic activity and the respiration rate is higher than whole produce due to residual respiration. Residual respiration does not produce ATP but contributes consistently to O2 consumption.

SIGNIFICANCE OF RESPIRATION

Respiration plays a major role in the postharvest life of fresh fruits and vegetables. Respiration continues even after harvest. After harvest the produce is dependent entirely upon its own food reserves as no replenishment is there. Therefore, losses of respiratory substrates and moisture are not made up and deterioration has started. Produce' possessing a high respiration rate can be stored for longer time duration. An enhanced respiration rate is associated with perishability of food. The significant effects of respiration are:

- **Loss of substrates:** The process of respiration utilizes various substrates and thus results in loss of food reserves in the tissue, loss of taste quality and food value. During the extended storage the loss in weight can be highly significant.
- **Oxygen consumption**: For aerobic respiration, presence of oxygen is must. Reduction of oxygen concentration is a useful tool for controlling respiration rate and slowing down the senescence.
- **Carbon Dioxide production:** Accumulation of CO2 produced due to respiratory metabolism can be beneficial or harmful. Carbon dioxide concentration is also used as an effective measure for delaying senescence.

• **Release of Heat:** As respiration is exothermic in nature, heat generated raises the temperature of produce. The heat generated is one of the prime consideration for designing the packaging/ storage of horticultural crops.

• **Shelf life indicator:** Respiratory process indicates the metabolic activity of living produce and determines the post-harvest physiology and deteriorative ability of plant produce. Respiration rate is well correlated with rate of deterioration, and thus is a good measure of the storage potential of the plant produce. Generally, a higher respiration rate indicates shorter shelf life.

• **Classification:** Respiration rate is an important criterion to compare perishability of fruits and vegetables. Depending upon respiratory rate Kader and Barrett classified fruits and vegetables into five different classes, rate as shown below:

Table1. Classification of fruits and vegetables on the basis of respiration rate.

	Respiration rate (mg CO_2/ kg/ h)		
Class	**10 °C**	**20°C**	**Examples**
Very Low	<10	<40	Nuts, dates, dry fruits
Low	10	40	Potatoes, onion cucumber, apple pear kiwifruit, pomegranate
Moderate	10-20	40-80	Pepper, carrot, tomato, eggplant, citrus fruit, banana
High	20-40	80-120	Peas, radish, apricot, fig, ripe avocado, papaya
Very High	>40	>120	Mushrooms, green onion, cauliflower, dill, parsley, melons, okra, strawberry , blackberry, raspberry

Source: Data from I. Burzo. Acta Hortic. 116:61, 1980; A. A. Kader and D. M. Barrett. In Processing Fruits: Science and Technology, Vol. 1, Biology, Principles, and Applications. (L. P. Somogyi, H. S. Ramaswamy, and Y. H. Hui, Eds), Technomic Publishing Co., Pennsylvania, 2003, p. 1.

• **Change in quality:** The physiological processes leading to enhanced quality (e.g., color development, softening, astringency loss, and aroma production) are deeply influenced respiration. Extremes in respiration rate results in the development of specific physiological disorders, resulting in loss of quality. Respiration is beneficial in providing carbon skeleton intermediates for pigment synthesis, flavor development, formation of ripening enzymes, fats, sterols etc.

RESPIRATORY QUOTIENT

The ratio of moles of CO2 Produced per mole of O2 consumed is called the respiratory quotient. RQ is as an indication of which substrates are being used in the respiratory pathway. RQ is 1 for glucose catabolism. When substrates other than glucose are respired, the RQ is

different than 1. RESPIRATION MEASUREMENT The rate of any reaction can be determined by measuring the rate at which the substrates disappear or the products appear. The measurement of respiration is very important because of its association with cell metabolism because the energy derived from respiration drives all other reactions within a cell. Measurement of Respiratory gas exchange is often used as a general measure of the metabolic rate of tissues. It was first conducted by Kidd on pea and mustard seeds in 1917. The respiration rate can be determined by measuring the O2 and CO2 concentrations in the atmosphere surrounding the product, determination of loss of dry weight, heat production and loss of energy content. Determination of gas exchange is the most convenient means of measuring respiration rate. It is known, however, that gas concentrations inside the product differ from the concentrations outside due to diffusion barriers exiting between the external atmosphere and respiration seat (mitochondria). Therefore, bulky intact fruits respond to O2 concentrations differently than cell cultures. There are various ways of measuring gas exchange, but the three methods used most often are:The RQ can also exceed 1 when O2 is not involved, such as in fermentation. RQ values below 1 are expected when lipids or proteins, molecules often containing less oxygen than carbohydrates, are respired.

- **Static method:** In the closed system, a gas-tight container of known volume is filled with product and the container, containing ambient air as the initial atmosphere, is closed. The changes in concentration of O2 and CO2 over time duration are measured to estimate the respiration rates.
- **Flow through method:** In the flow through system, the product is enclosed in an impermeable container through which a gas mixture flows at a constant rate. The respiration rates are calculated from the absolute differences in gas concentrations between the outlet and the inlet when the system reaches steady state.
- **Permeable method:** In the permeable system, a package of known dimensions and film permeability is filled with product. The steady-state concentrations of O2 and CO2 are determined and a mass balance is performed on the system in order to estimate the respiration rates.

FACTORS AFFECTING RESPIRATION

Temperature

The temperature dependence of respiratory rate varies among and within commodities.

Generally, the respiration increases significantly as the storage temperature increases. Within the physiological range of temperature (0°C–30°C), the rate of respiration increases exponentially, and a large amount of heat is produced as heat of respiration. The relationship between temperature and respiration rate can be expressed in the form of Q values, which allows the estimation of the rate of respiration at an unknown temperature provided the rate of respiration at a known temperature is available. The rate of respiration is described mathematically by use of temperature quotient (Q10),

$$Q_{10} = \left(\frac{q_2}{q_1}\right)^{\left(\frac{10}{T_2 - T_1}\right)}$$

where, q2 and q1 are rate of respiration at temperature T2 and T1 respectively. The plant metabolism is drastically affected, not only when temperature is increased but also under reduced temperature conditions. Thus the system undergoes heat stress or chilling stress

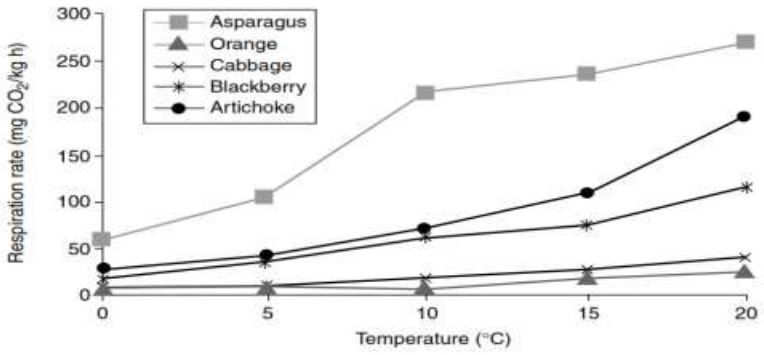


Figure 2.3 Effect of temperature on the respiration rates of some fruits and vegetables. (Data taken from K. C. Gross et al. The Commercial Storage of Fruits, Vegetables, and Florist and Nursery Stocks—A Draft Version of the Revision to USDA Agricultural Handbook Number 66 (2002) (revised in 2004) (www.ba.ars.usda.gov/hb66/index.html.)

Heat Stress

If the temperature rises beyond the physiological range, respiration rate falls. When tissue reaches its thermal death point, metabolism is disordered as enzyme proteins are denatured. Continued exposure to high temperatures causes phytotoxic symptoms and tissue collapse.

Chilling stress

Although respiration is normally reduced at low, but non-freezing temperatures, certain commodities particularly those originating in the tropics and subtropics, exhibit abnormal

respiration when their temperature falls below 10 to 12 °C. Respiration may increase dramatically at the chilling temperatures or when the commodity is returned to nonchilling temperatures. Enhanced respiration rate is cells' effort to detoxify metabolic intermediates that accumulated during chilling, as well as to repair damage to membranes and other sub-cellular structures. Enhanced respiration is one of the symptoms that signal the onset of chilling injury.

Oxygen and carbon dioxide

A slight reduction of oxygen concentration does not have any adverse effect on produce, but a comparable increase in carbon dioxide may cause deteriorative changes in fruits and vegetables. The injury threshold of various fruits and vegetables to O2 varies considerably. Reduction of O2 concentration below 2%–3% gives beneficial reduction in rates of respiration and other metabolic processes for most produce. Increasing the CO2 level around some commodities reduces respiration, delays senescence and retards fungal growth. However, complete removal of O2 is not recommended as anaerobic environment is detrimental to the quality of the produce as it leads to fermentation, decay and development of off flavor, and change in color and texture.

Stage of development

Respiration rates vary due to stage of the development. Storage organs such as nuts and tubers have low respiration rates. Tissues with vegetative or floral meristems such as asparagus and broccoli have very high respiration rates. The commodities harvested during active growth, such as many vegetables and immature fruits, have high respiration rates. Mature fruits, dormant buds and storage organs have relatively low rates.

Table 2. Classification of tissue on basis of respiration rate

Respiration rate	Type of tissue
High	Young tissues, meristematic tissues, growing plants (asparagus), partly developed flower buds (broccoli), developing seeds (green bean, peas), immature fruit (sweet corn, okra)
Intermediate	leafy vegetables (spinach, cabbage), unripe fruit (cucumbers)
Low	storage organs roots (sweet potato), tubers (potatoes), bulbs (onions), mature fruits (pumpkins)

After harvest, the respiration rate typically declines; slowly in non-climacteric fruits and storage organs, rapidly in vegetative tissues and immature fruits. The rapid decline presumably reflects depletion of respirable substrates that are typically low in such tissues.

Stress/ Injury

Physical stress during cultivation, harvesting, and postharvest handling influences respiratory behaviour significantly. Tissue injury increases the rate of respiration and induces ethylene production, which may further catalyse an increase in respiration with consequent loss of quality. However, in some tissues wounding stimulates developmental changes, e. g., promote ripening, that result in a prolonged increase in respiration. The extent of increase in respiration rate is usually proportional to the severity of bruising. Water stress which is induced by lower than optimal relative humidity in air surrounding the commodity can stimulate its respiration rate. However when water loss exceeds about 5% the respiration rate is reduced, but at the same time wilting and shrivelling becomes noticeable. Biological stress like disease also increases the respiration rate. Other stresses that stimulate the respiration rate of vegetables including exposure to ionizing radiation and to various chemicals such as methyl bromide (fumigant) etc.

Other

- **Surface of tissue:** Thickness of surface dermal system, wax composition and arrangement, number and distribution of stomata on the tissue influences the respiration rate. More the thickness of coating, less is the respiration rate.
- **Surface to volume ratio:** Smaller fruits large surface area, high respiration rate.
- Growing conditions: Cultural practices, irrigation, fertilizer also influence the respiration rate. High nitrogen fertilizer increases respiration while high calcium fertilizer decreases respiration.
- **Application of chemicals:** Certain chemicals like malic hydrazide, methyl cyclopropene (MCP), polyamines like putrescine, spermidine and spermine slows down the rate of the ethylene production and respiration while application of ethylene, acetylene, propylene, ethephon has a positive effect on respiration rate due to positive impact on ethylene (ripening hormone) generation.

CONTROLLING RESPIRATION

Respiration rate is most affected by altered atmospheres and the temperature. The alteration in these two factors forms the basis of storage of horticultural produce upon harvest.

The low temperature storage with right relative humidity is particularly beneficial for produce and helps in increasing the shelf life to an acceptable level. Similar effects are achieved by modified storage methods. Decreased O2 and increased CO2 levels also influence ethylene production and action and suppress microbial growth. Nowadays, low O2 and high CO2 concentrations are involved in several storage or packaging methodologies. The most common being, controlled atmosphere (CA) and modified atmosphere (MA) storage. CA storage generally refers to decreased O2 and increased CO2 with monitoring and active adjustment of the gas composition, whereas MA refers to a difference in gas composition as compared with ambient air, without any active control of the gas composition. The antisenescence agents like polyamines, maleic hydrazide, MCP are also applied to control respiratory rates.

Conclusion

Respiration is breakdown of complex substrates with concurrent production of energy and useful carbon skeletons. Respiration rate is an excellent indicator of metabolic activity of the tissue and a very useful guide for potential storage life of the horticultural produce. The process is affected by numerous external and internal factors particularly important being temperature and concentration of oxygen and carbon dioxide. The primary aim of any fruit and vegetable technologist is to alter these external factors for maximizing the shelf life of the produce with minimal of biochemical changes, thus preserving the food value in itself. Measurement and modelling of respiration rate for any particular crop provides an efficient means for the optimal storage conditions for that particular crop.

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STRESS RESPONSE AND MANAGEMENT IN PLANTS: MECHANISMS BEHIND RESILIENCE

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Abstract

India has just registered its all-time high temperature at 52.9 degrees Celsius in a part of Delhi. Only a decade ago, the maximum temperature in Delhi was 47.8 degrees Celsius. Such a rise of more than 5.1 degrees is astonishing and points towards a problem that must be given immediate attention. Climate change is now a prime area of research because of the huge impact it has on food production systems. Millions of humans all over the world are undergoing famine, and equatorial nations are most susceptible since their crops are more prone to be affected first.

Global warming is drying up our water supplies, and the widespread prevalence of drought puts pressure on crops, eventually reducing harvests. Yet, if plants were super sensitive to this, food output would have already stopped decades ago. Luckily, plants have special mechanisms to control these stress factors. This review article discusses the different mechanisms through which plants adapt to combat these challenges and how knowledge of these mechanisms can contribute to the development of new traits towards making plants stronger.

Keywords: climate change, drought, stress, high temperatures, global warming.

Introduction

"Stress is generally defined as an external agent that adversely affects plants" (Lincoln Taiz and Eduardo Zeiger, 2002). Stress may be caused by both biotic and abiotic sources. Biotic sources include insect pests, diseases, and competition among plant species. Abiotic sources, on

the other hand, include fluctuations in air temperature, soil water, and soil salinity etc... When the plant undergoes stress, it is influenced by certain changes in its cell cycle, division of cells, structure of the cell walls, as well as the vacuoles of the cells. The water potential of the plant cells lowers, and the solute potential rises, causing decreased turgor pressure on the cell walls. The solution to the cell wall becomes a bit acidic, and there is relaxation of the cell wall as well as plasma membrane thickening. Therefore, cells contract in volume. Due to this, the cells get shorter in length, which is why wilting or loss of leaf size becomes an evident initial sign in plants during times of stress conditions. The plant growth stage is also a factor to be taken into consideration since the response to stress differs based on this stage. For instance, if a plant is in the vegetative stage when experiencing drought, it will allocate all resources to the roots and not the reproductive organs. Conversely, if a plant is in the budding, flowering, or fruiting phase, it will allocate resources to these structures, since its primary goal is to mature and enter a dormant condition.

Abiotic Stress Response and Management:

The reduced rate of growth caused by low photosynthetic efficiency initiates the build-up of compatible solutes such as proline and mannitol in the cytoplasm of the cell. Pyrroline carboxylase synthase is an important enzyme that becomes upregulated during this process, resulting in higher levels of proline. The osmotic adjustment comes into effect when the water potential of the tissue starts to be impacted. Osmotic adjustment is a fascinating process by which plants take in water tightly packaged in tiny soil pores. All these alterations within the plant body take place with time. But if the temperature suddenly increases during a single day, how would the plants adjust to this quick change?

To deal with stress, plants synthesize a particular set of proteins called heat shock proteins (HSPs). The function of these proteins is to forestall the misfolding of other proteins in the plant. But plants are always subjected to oxygen and UV light from sunlight. Exposure to these along with heat stress might give rise to hydrolytic degradation of DNA. Sunlight possesses a lot of energy, one that is capable of exciting electrons and ionizing water molecules within the plant. When this happens, it produces reactive oxygen species (ROS). Of all the

various forms of ROS formed, hydroxyl radicals (OH-) are especially known for how quickly they react with DNA, which leads to cellular destruction.

Interestingly, ROS can be a double-edged sword. If kept at the right levels, ROS are an efficient stress response mechanism. However, disruption of this balance is deleterious to plants since an overproduction of ROS causes photo-oxidative stress. Photo-oxidative stress has the potential to result in lipid peroxidation, photosystem damage, and cell death. In order to preserve cellular integrity, plants generate different antioxidants, including peroxidases, ascorbic acid, carotenoids, and superoxide dismutase.

Biotic Stress Response and Management

Under biotic stress, the plant releases a range of different hormones to resist the stress. For instance, when a plant is invaded by a pathogen, the plant can detect the presence of the pathogen due to pathogen-associated molecular patterns (PAMPs) that the invaders possess, which are sensed by the pattern recognition receptors (PRRs) of the plant. Such pathogens release specific proteins, lipids, or carbohydrates that do not occur naturally in the plant, e.g., chitin released by fungi. The activation of PRRs initiates a cascade of cellular signaling pathways. The cascade comprises the production of reactive oxygen species (ROS) and the induction of some enzymes and proteins. Eventually, all these processes contribute to the biosynthesis of antimicrobial compounds, cell wall fortification to ensure that no additional pathogens enter the cell, and the induction of plant defense genes.

Over time, pathogens have adapted, secreting effector proteins that suppress the plant's immunity, allowing them to more easily gain entry into the plant body. Plants counter this by using effector-triggered immunity (ETI) as a more powerful defense system. Plants possess resistance genes, or R genes, and can recognize these effector proteins, triggering a hypersensitive response. This process entails programmed cell death in the vicinity of the infected tissue, thus blocking the spread of the pathogen to other areas of the plant and confining it in that zone. The impact of this localized response is seen across the plant. Infected cells communicate stress signals to healthy tissues, which initiate a defensive response and get the plant ready for any future attack. It is to be noted that biotic stress is not only due to pathogens; mechanical injury also leads to biotic stress. Here the jasmonic acid pathway comes into play in inducing a defensive response by upregulating defense gene expression.

Conclusion

Plants have evolved numerous incredible mechanisms to deal with different adversities. It is remarkable that, being immobile, they are able to survive under numerous stresses. Yet, numerous pathways and mechanisms in plants are unknown to human beings and are yet to be explored.

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CLIMATE CHANGE AND ITS IMPACT ON MULBERRY CULTIVATION: ADAPTIVE STRATEGIES

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Abstract

This paper examines the significant threat climate change poses to global sericulture (silk production). Rising temperatures, altered precipitation patterns, and increased frequency of extreme weather events directly impact the delicate lifecycle of the Bombyx mori silkworm and the cultivation of its primary food source, mulberry. These changes disrupt silkworm growth, cocoon quality, and silk yield, while also exacerbating pest and disease pressures. Indirect effects include soil degradation and biodiversity loss, further stressing the sericulture ecosystem. The socioeconomic stability of communities reliant on this industry is consequently endangered. To address these challenges, the paper details critical adaptation strategies. These include developing climate-resilient silkworm breeds and mulberry varieties, implementing improved water management and integrated pest management practices, adopting technological innovations like precision agriculture and climate forecasting, and securing supportive policy frameworks. Effective implementation of these multifaceted strategies is essential for enhancing resilience and ensuring the sustainability of sericulture in a changing climate.

Introduction

Sericulture, the practice of cultivating silkworms for the production of silk, has a rich history dating back thousands of years. In this overview, we will delve into the biology and lifecycle of the silkworm (Bombyx mori), explore the major regions of sericulture production worldwide, and discuss the economic and cultural significance of sericulture in

various countries. Silkworms, the larval stage of the domestic silk moth Bombyx mori, play a central role in sericulture. The lifecycle of the silkworm consists of four main stages: egg, larva, pupa, and adult moth. The process begins with the laying of eggs by the adult moth, typically on specially prepared paper or leaves. These eggs hatch into larvae within approximately 10 days. The larval stage, or caterpillar stage, is the most crucial phase for silk production. During this stage, the silkworms feed voraciously on mulberry leaves, growing rapidly and molting several times as they increase in size. This period lasts around 4-6 weeks, after which the silkworms enter the pupal stage. In the pupal stage, the silkworm spins a protective cocoon around itself using silk produced from specialized glands. This cocoon serves as the silkworm's shelter as it undergoes metamorphosis into an adult moth. The pupal stage typically lasts for about 2-3 weeks, depending on environmental conditions. Once the metamorphosis is complete, the adult moth emerges from the cocoon. However, in commercial silk production, the cocoons are usually harvested before the adult moth can emerge to prevent damage to the silk fibers. The harvested cocoons are then boiled to soften the silk fibers, which are unwound to produce raw silk.

CLIMATE CHANGE AND ITS IMPACTS:

Climate change refers to the long-term alteration of temperature, precipitation patterns, and other meteorological factors on Earth's surface, primarily driven by human activities such as the burning of fossil fuels and deforestation. The current state of climate change is marked by unprecedented global warming, evidenced by rising average temperatures, melting glaciers, and shifting weather patterns.

The impacts of climate change on agriculture are profound and multifaceted, posing significant challenges to global food security. Agriculture, including sericulture, is particularly vulnerable due to its reliance on specific environmental conditions. Climate change encompasses a range of phenomena, but at its core, it involves alterations in Earth's climate system. The Intergovernmental Panel on Climate Change (IPCC) defines climate change as "a change in the state of the climate that can be identified by changes in the mean and/or variability of its properties, and that persists for an extended period, typically decades or longer, whether due to natural variability or as a result of human activity". The current state of climate cha nge is alarming. Global temperatures have risen by approximately 1.2 degrees Celsius above preindustrial levels, with significant consequences for ecosystems, weather

patterns, and human societies. The primary driver of this warming trend is the increased concentration of greenhouse gases in the atmosphere, particularly carbon dioxide emitted from activities such as burning fossil fuels and deforestation.

General Impacts of Climate Change on Agriculture:

The impacts of climate change on agriculture are diverse and far-reaching. One of the most pronounced effects is the rise in temperatures, which can lead to heat stress in crops and livestock, affecting growth rates, reproductive success, and overall productivity. Altered precipitation patterns, including changes in the frequency and intensity of rainfall, pose challenges for crop irrigation, water management, and soil erosion control. Extreme weather events such as droughts, floods, hurricanes, and wildfires are becoming more frequent and intense due to climate change, causing crop losses, infrastructure damage, and disruptions to supply chains. These events exacerbate food insecurity and economic instability, particularly in regions with limited adaptive capacity and resources. Sericulture, the practice of rearing silkworms for the production of silk, is intricately linked to climatic conditions. Silkworms, specifically the domesticated Bombyx mori species, are highly sensitive to environmental factors such as temperature, humidity, and photoperiod. Rising temperatures can disrupt the delicate balance required for silkworm development, affecting their growth, cocoon quality, and survival rates. Shifts in precipitation patterns may alter the availability of mulberry leaves, the primary food source for silkworms, leading to fluctuations in silk production and quality. Extreme weather events, such as storms and heatwaves, pose direct threats to silkworm colonies and silk production facilities, potentially causing substantial economic losses for sericulture industries. Additionally, climate change may exacerbate the spread of pests and diseases that affect silkworms, further impacting silk yields and quality. Climate change presents significant challenges for agriculture, including sericulture, due to its impacts on temperature, precipitation, and extreme weather events. Adapting to these changes requires innovative strategies and investments in research, technology, and policy interventions to ensure the resilience and sustainability of sericulture systems in the face of a changing climate.

Direct Impacts of Climate Change on Sericulture:

Sericulture, the practice of silk production through the rearing of silkworms, has been deeply intertwined with human culture and economies for centuries. However, the effects of

climate change are increasingly posing challenges to this delicate industry. The direct impacts of climate change on sericulture encompass various aspects, including temperature fluctuations, changes in precipitation patterns, increased pest and disease incidences, and extreme weather events. Understanding these impacts is crucial for devising effective adaptation strategies to sustain sericulture in the face of climate change**.**

Temperature Fluctuations and Silkworm Growth

Temperature plays a critical role in the growth and development of silkworms. As climate change leads to temperature fluctuations, it directly affects the life cycle of silkworms. High temperatures can accelerate silkworm development, leading to premature emergence and lower silk quality. Conversely, low temperatures can prolong the larval stage, delaying cocoon formation and reducing silk yield. Research by Zhang et al. found that even slight deviations from optimal temperatures can significantly impact silkworm growth rates. Changes in Precipitation Patterns and Mulberry Cultivation Mulberry leaves are the primary food source for silkworms, and any changes in precipitation patterns directly affect mulberry cultivation. Alterations in rainfall patterns, such as prolonged droughts or excessive rainfall, can disrupt mulberry growth cycles, leading to decreased leaf quality and quantity. This, in turn, affects the health and productivity of silkworms. Studies by Li et al. have highlighted the vulnerability of mulberry plants to water stress and the need for adaptive irrigation strategies in sericulture.

Increased Incidence of Pests and Diseases

Climate change contributes to the proliferation of pests and diseases, posing significant threats to both silkworms and mulberry plants. Warmer temperatures create favourable conditions for the breeding and spread of pests such as mites and pathogens like fungal infections. These infestations not only directly harm silkworms and mulberry plants but also reduce silk quality and yield. Effective pest management strategies, including integrated pest management approaches, are essential to mitigate these impacts.

Extreme Weather Events and Sericulture Infrastructure*:*

Extreme weather events, such as droughts and floods, are becoming more frequent and intense due to climate change. These events can cause substantial damage to sericulture infrastructure, including silk production facilities, mulberry plantations, and silkworm rearing units. Floods can wash away mulberry fields, while droughts can lead to water scarcity for

silkworm rearing. Investments in resilient infrastructure and disaster preparedness are imperative for ensuring the continuity of sericulture in regions prone to extreme weather events. The direct impacts of climate change on sericulture encompass various interconnected factors, including temperature fluctuations, precipitation changes, pest and disease incidences, and extreme weather events. Addressing these challenges requires a multi-faceted approach that integrates scientific research, technological innovations, and adaptive management strategies. By understanding and mitigating the effects of climate change on sericulture, stakeholders can safeguard this ancient industry and ensure its sustainability for future generations.

Indirect Impacts of Climate Change on Sericulture:

Sericulture, the cultivation of silk-producing insects, predominantly relies on the mulberry plant (Morus spp.) for sustenance. However, climate change-induced alterations in temperature, precipitation, and ecological dynamics pose significant challenges to this delicate ecosystem. While the direct effects of climate change are evident, understanding its indirect impacts is equally imperative for devising effective adaptation strategies.

Soil Degradation and Changes in Soil Fertility Affecting Mulberry Quality*:*

Climate change exacerbates soil degradation through increased erosion, salinization, and nutrient depletion. These alterations directly influence mulberry growth and silk production. Studies indicate that rising temperatures and erratic rainfall patterns can diminish soil fertility, impeding mulberry cultivation. Additionally, elevated CO2 levels may alter nutrient uptake mechanisms in mulberry plants, further affecting silk quality. To mitigate these impacts, implementing soil conservation measures such as contour ploughing, cover cropping, and organic amendments is crucial.

Soil Degradation and Changes in Soil Fertility Affecting Mulberry Quality

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Altered Ecosystems and Biodiversity Loss Impacting Sericulture

Climate change disrupts ecosystems, leading to biodiversity loss and habitat degradation. This, in turn, affects the natural predators and prey of silk-producing insects, thereby disrupting the delicate ecological balance essential for sericulture. For instance, alterations in temperature and precipitation regimes may favour the proliferation of pests and diseases detrimental to silkworms. Conservation efforts aimed at preserving biodiversity hotspots and restoring degraded habitats are imperative for safeguarding sericulture-dependent ecosystems.

Socio-economic Impacts on Communities Dependent on Sericulture

Communities reliant on sericulture for livelihoods face multifaceted socio-economic challenges exacerbated by climate change. Fluctuations in silk production due to environmental variability directly impact income stability and food security among sericulture-dependent populations. Moreover, extreme weather events like floods and droughts can devastate silk farms, leading to economic losses and exacerbating poverty. Strengthening community resilience through diversification of income sources, access to climate-smart agricultural practices, and social safety nets is essential for mitigating the socioeconomic impacts of climate change on sericulture-dependent communities [26]. The indirect impacts of climate change on sericulture underscore the need for holistic adaptation strategies encompassing soil conservation, biodiversity preservation, and socio-economic resilience building. By addressing these facets, policymakers, researchers, and stakeholders can forge pathways towards sustainable sericulture amidst a changing climate. Collaboration among diverse stakeholders, coupled with innovative technologies and policy interventions, is imperative for safeguarding this ancient yet fragile industry.

ADAPTATION STRATEGIES FOR SERICULTURE UNDER CLIMATE CHANGE:

Sericulture, the practice of silk production, has been a significant aspect of many cultures for centuries. However, the impact of climate change presents a substantial challenge to the sustainability and productivity of sericulture. Rising temperatures, erratic rainfall patterns, and the increasing frequency of extreme weather events threaten the delicate balance required for successful silk production. In response, adaptation strategies are crucial for mitigating these risks and ensuring the resilience of sericulture systems. Development and Use of Climate- Resilient Silkworm and Mulberry Varieties: One key adaptation

strategy involves the development and utilization of climate-resilient silkworm and mulberry varieties. Traditional varieties may not be equipped to withstand the changing climate conditions, making them more susceptible to stressors such as heatwaves or drought. Through selective breeding and genetic engineering techniques, researchers can develop varieties that exhibit traits such as heat tolerance, pest resistance, and improved productivity under altered climate conditions. These resilient varieties can help safeguard sericulture against the adverse effects of climate change.

Improved Sericulture Practices:

Adapting sericulture practices to changing climatic conditions is essential for maintaining productivity and minimizing risks. This includes optimizing mulberry cultivation techniques to ensure efficient water use and nutrient management in the face of altered precipitation patterns. Additionally, advancements in silkworm rearing methods, such as temperature and humidity control in rearing facilities, can help mitigate the impacts of temperature extremes on silkworm health and productivity. Implementing best management practices tailored to the specific climatic challenges of each region is crucial for sustainable sericulture.

Integrated Pest and Disease Management:

Climate change can exacerbate the prevalence and distribution of pests and diseases in sericulture systems, posing significant threats to silk production. Integrated pest and disease management approaches, which combine biological, cultural, and chemical control methods, are essential for mitigating these risks sustainably. For example, introducing natural predators of common silk pests or employing pheromone-based traps can help control pest populations without relying solely on chemical pesticides, which may become less effective due to shifting pest dynamics under climate change.

Water Management Strategies for Mulberry Cultivation:

Water scarcity and erratic precipitation patterns resulting from climate change pose significant challenges to mulberry cultivation, which is a water-intensive crop. Implementing water management strategies such as drip irrigation, rainwater harvesting, and efficient water storage systems can help optimize water use efficiency and ensure the sustainable cultivation of mulberry even in water-stressed environments. Furthermore, integrating mulberry cultivation with agroforestry or aquaculture systems can create

synergies that enhance water conservation and overall resilience. Technological Innovations: Advancements in agricultural technologies offer promising solutions for enhancing the resilience of sericulture systems to climate change. Precision agriculture techniques, including remote sensing and geographic information systems (GIS), enable farmers to monitor and manage their crops more effectively, optimizing resource use and reducing environmental impact. Climate forecasting tools provide valuable information for anticipating weather-related risks and implementing timely adaptive measures, such as adjusting planting schedules or implementing protective measures during extreme weather events.

Policy Support and Funding:

Effective adaptation to climate change in sericulture requires strong policy support and adequate funding for research and development initiatives. Governments and international organizations play a crucial role in facilitating knowledge exchange, capacity building, and the dissemination of best practices among sericulture stakeholders.

Investing in research and development programs focused on climate resilient sericulture varieties, innovative technologies, and sustainable practices is essential for ensuring the long-term viability of the silk industry in the face of climate change. Adaptation strategies for sericulture under climate change are multifaceted and require a holistic approach that integrates technological, agronomic, and policy interventions. By developing climate-resilient varieties, optimizing cultivation practices, managing pests and diseases effectively, and harnessing technological innovations, sericulture can continue to thrive in the face of evolving climatic challenges. However, concerted efforts from governments, researchers, industry stakeholders, and farmers are necessary to implement these strategies effectively and ensure the sustainability of silk production for future generations.

Conclusion

Climate change poses significant challenges to sericulture, impacting silk production worldwide. In this paper, the close link between climate change and sericulture has been described in detail. We established how increase in temperature, inconsistent rainfall, and other related disasters upset the sensitive conditions necessary for silk making. These environmental changes influence mulberry plant, silkworm, and cocoon, which in turn

influence the quality and quantity of silk production. Furthermore, we looked into different actions taken by different stakeholders in the sericulture industry to minimize the impact of climate change. Some of these strategies include crop diversification, planting of drought resistant silkworm mulberry varieties and using ecological silkworm breeds and practices. Similarly, remote sensing techniques and GIS mapping are some of the most important technologies that can help in early detection and management of the sericulture ecosystems changes due to climate variability.

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AFLATOXICOSIS: A SILENT THREAT TO ANIMAL AND PUBLIC HEALTH

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Abstract

Aflatoxicosis is a globally significant mycotoxicosis that arises from ingestion of aflatoxin-contaminated feed, particularly stored under hot and dry conditions. Produced by *Aspergillus flavus* and *A. parasiticus*, aflatoxins—especially AFB_1—are potent hepatotoxins and Group 1 carcinogens (WHO). These toxins impair animal health through hepatotoxicity, immunosuppression, carcinogenesis, and reproductive dysfunction, with susceptibility influenced by species, age, and nutrition. Ruminants show variable tolerance to aflatoxicosis due to ruminal detoxification, though chronic exposure leads to severe hepatic, neurological, and reproductive problems. Monogastric animals like horses, pigs, and dogs, along with poultry, display acute to chronic toxicity with liver damage, haemorrhages, anorexia, icterus, and high mortality—especially in young animals. Aflatoxin residues, particularly AFM_1 in milk, pose significant public health risks. Control strategies include pre- and post-harvest surveillance, feed testing, dietary support, and use of aflatoxin binders such as hydrated sodium calcium aluminosilicates (HSCAs). Although treatments are limited, prevention through quality control and nutrition remains the cornerstone of aflatoxicosis mitigation in animal and public health systems.

Overview

Aflatoxicosis is a globally prevalent mycotoxicosis resulting from the ingestion of aflatoxin-contaminated feed, particularly stored under hot and dry conditions. Its occurrence is frequently associated with insect damaged crops, both during cultivation and post-harvest storage. The condition was first identified during the 1960 as “Turkey X” outbreak in England

caused by toxic groundnut meal imported from Brazil, which finally led to the discovery of aflatoxins. Aflatoxins are toxic metabolites produced by *Aspergillus flavus* and *A. parasiticus*, commonly found in peanuts, maize, cottonseed, and almonds. Seventeen aflatoxins have been identified, but B1, B2, G1, and G2 are the most studied due to their toxicity and fluorescence under UV light. Aflatoxins M1 and M2 are secondary metabolites found in milk following B1 and B2 ingestion. Toxigenic *A. parasiticus* isolates typically produce aflatoxins B1, B2, G1, and G2, while isolates of *A. flavus* typically only produce aflatoxins B1 and B2. Aflatoxin B1 (AFB1) is the most toxic and carcinogenic, which is classified as a Group 1 carcinogen by World Health Organization (WHO). Once ingested, Aflatoxin B1 is metabolized in the liver to reactive epoxides that bind to nucleic acids, causing hepatotoxicity, immunosuppression, carcinogenesis, mutagenesis, and reproductive issues. Clinically, animals may show reduced growth, icterus, feed refusal, hemorrhage, and even death. Exposure occurs mainly via ingestion, but dermal and inhalation routes also contribute. Susceptibility varies with species, age, sex, and nutrition.

Public Health Concern

Feeding of aflatoxin-contaminated feed to farm animals can harm their health and also lead to carry-over of toxins in milk and meat, increasing the risk of human exposure to aflatoxins. Regulatory agencies have set a maximum tolerance of 20 ppb in animal feed. Aflatoxins can damage the liver in both human and animals, and can lead to serious conditions such as liver cancer or even death. AFB1 is especially hazardous, and its metabolite, aflatoxin M1, can be detected in milk.

Aflatoxicosis in animals

Depending on the species, age, dosage, and length of exposure, aflatoxin can result in oncogenesis, chronic toxicity, or per-acute symptoms. Aflatoxin can affect any animal species;however, outbreaks occur mostly in pigs, sheep, and cattle. Compared to sheep or horses, beef and dairy cattle are more prone to aflatoxicosis. Young animals are generally more susceptible to the effects of aflatoxins than adults. While pregnant and growing animals are more at risk than fully mature animals. Aflatoxin metabolites released in milk can have an impact on nursing animals. For most species, oral LD50 values of aflatoxin B1 vary from 0.03 to 18 mg/kg body weight. Aflatoxin susceptibility varies by species, but in general most animals, including humans, are affected in the same way.

Aflatoxicosis in ruminants

Cattle consuming aflatoxin-contaminated feed absorb only 2–5% of the toxin due to its binding with ruminal contents. Aflatoxin B1 (AFB1) levels above 100 µg/kg in feed are considered toxic. Susceptibility depends on toxin concentration, duration of exposure, and animal age. The estimated LD_{50} of AFB1 in calves is 0.5–1.5 mg/kg. Prolonged intake causes keratoconjunctivitis, oedema, jaundice, depression, anorexia, dysentery, and death. Gross lesions include widespread hemorrhages and pale and indurated liver, while histopathology shows hepatocellular karyomegaly, fatty degeneration, cirrhosis and elevated liver enzymes. Neurological signs like circling, blindness, ear twitching, and rectal erosion are common. Acute toxicosis in adult cattle manifests as anorexia, severe milk drop, weight loss, icterus, abdominal pain, dysentery, abortion, hepatic encephalopathy, and photosensitization. Neurologic signs (e.g., blindness, circling) and keratoconjunctivitis may also appear. Liver lesions include fatty changes, megalocytosis, necrosis, fibrosis, and bile duct proliferation.



Fig.1. Chicken liver lesions when subjected to 184 ppb aflatoxin contaminated diet: Liver showed increase in size, pallor, and haemorrhage, particularly on the left lobule. The typical colour (dark brown) of liver is lost.



Fig.2. Cattle liver lesions with 250 ppb aflatoxin contaminated feed: Liver showed increase in size, induration and yellowish discoloration.

Chronic exposure leads to immunosuppression, reproductive issues (irregular estrus, abortions), reduced milk yield, poor growth, mastitis, respiratory issues, and hair loss. Aflatoxins impair rumen function, reduce cellulose digestion, and disturb metabolic and hormonal balance. Sheep and goats exposed to aflatoxins exhibit icterus, depression, anorexia, and species-specific

signs like dark brown urine in sheep and nasal discharge in goats. In sheep, doses as low as 0.23 mg/kg cause anorexia and diarrhoea, while higher doses (≥0.59 mg/kg) lead to pyrexia, tachypnea, and hypersalivation. Severe mucous diarrhoea and dysentery occur at 1.28–2.0 mg/kg. Acute toxicity at 4 mg/kg results in fever, rumen atony, rectal prolapse, and death. Liver lesions include centrilobular necrosis, sinusoidal dilation, and periportal congestion.

Aflatoxicosis in horses, dog and pigs

Aflatoxin doses of 500–1000 µg/kg in equines cause centrilobular liver necrosis and clinical signs like inappetence, depression, fever, tremors, ataxia, and cough. Necropsy reveals yellow-brown liver, icterus, haemorrhages, tracheal exudates, and dark urine. Dogs with aflatoxicosis revealed anorexia, depression, jaundice, prostration, haemorrhages, melena, and pulmonary oedema. Acute cases show vomiting, polydipsia, jaundice, and elevated liver enzymes, while the post-mortem findings revealed petechiae in multiple organs, hepatomegaly, yellow-orange liver, and icterus of mucous membranes and fat.

Aflatoxin sensitivity is highest in young pigs, although it decreases with age. Young pigs are highly susceptible. Signs in pigs include anorexia, poor growth, icterus, tremors, bloody stools, and immunosuppression. Grossly, liver appear pale, fibrotic, and firm with atrophic gallbladder. Histology reveals centrilobular necrosis, nuclear damage, vacuolation, bile duct proliferation, and fibrosis.

Aflatoxicosis in Poultry

Aflatoxin susceptibility in poultry varies by species, breed, and genetic line. Aflatoxin sensitivity is highest in ducklings and turkey poultry, according to comparative toxicological investigations in avian species. It leads to major economic losses in ducklings, broilers, layers, turkeys, and quail. Susceptibility varies by species and genetics, with ducklings and turkey poults being most sensitive, followed by goslings > pheasant chicks > chickens (most resistant). Effects include mortality (especially under heat stress), reduced egg production, anaemia, haemorrhages, liver damage (fatty degeneration), paralysis, poor growth, lameness, immunosuppression, and increased disease susceptibility.

Control and management approaches

Crops can become contaminated with the harmful secondary metabolites as mycotoxins either before or after harvest. Aflatoxins, in particular, pose a significant risk not only during cultivation but also throughout handling, processing, transportation, manufacturing, and storage.

By checking batches for aflatoxin content, use of contaminated feeds can be prevented. Aflatoxin generation should be predicted by local crop conditions, such as insect infestation and dryness. Therefore prior to use, feeds should be chemically analyzed for aflatoxins and weather patterns, particularly drought and insect infestations in crops during growth, should be monitored. Although ammoniation lowers aflatoxin contamination in grain, the US FDA has not yet approved its use in food animals in the US due to concerns about the byproducts that may be created. Also there is no specific antidote for aflatoxins. Hence aflatoxin-contaminated feed should be avoided, especially for young or nursing animals.

To promote healing, animals should be fed a high-quality food that includes vitamins, trace minerals, and protein (not too little or too much, considering liver damage). In order to bind aflatoxins and decrease absorption from the GI tract, many products are promoted as anti-caking agents. Hydrated sodium calcium aluminosilicates (HSCAs are an efficient aflatoxin binder that lessens the effects of aflatoxin when fed to pigs or poultry at a rate of 5 kg/tonne. Aflatoxin M1 in milk can be partially reduced and negative effects in pigs and poultry can be minimized by using HSCAs, but the residue is not completely removed.

Conclusion

It is challenging to make a definitive diagnosis of aflatoxicosis since a misdiagnosis of an animal with the disease can occur due to confounding signs. Toxin-related problems with in-farm productivity are readily neglected. Based on the facts, it is recommended that GMP (Good Manufacturing Practice) and HACCP (Hazard Analysis and Critical Control Points) be required as preventative measures. In order to respond quickly to a potential increase in toxin incidence brought on by regional climate change, countries should increase vigilance and implement additional preventive and control measures. This is because changing weather patterns make it more difficult to predict the colonization of aflatoxigenic fungi and the production of toxins. Lastly, given the importance of feed in food chain safety, nations should establish and enhance programs for monitoring aflatoxin in food.These programs should focus on managing risks effectively to reduce both the health problems and financial costs that aflatoxin can bring

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INFLUENCE OF LIGHT ON FLOWER INDUCTION IN DRAGON FRUIT

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Abstract

To meet the increasing demand for year-round production of dragon fruit (*Hylocereus polyrhizus*), which is limited by its natural flowering season in the summer. Efficient light-induced floral stimulation plays a key role in energy conservation and maintaining stable productivity during off-season periods of dragon fruit plants. Pitaya is a long-day (LD) plant, flowering naturally in May–October. Presently artificial light of the improved CFL lamp is commercialization potential stimulating flowering in dragon fruit growing areas. Moreover, the revolutionize the flowering physiology, the strategy to enhance year-round production and the advancement of agricultural sustainability in pitaya. Efficient light-induced floral stimulation plays a key role in energy conservation and maintaining stable productivity during off-season periods of dragon fruit plants.

Key words: Day length, dragon fruit, lighting duration, off-season

Introduction

Dragon fruit (*Hylocereus* spp.) also known as Pitaya, Strawberry pear, or Scaly fruit is a highly nutritious fruit that originated in tropical regions of central south America. Dragon fruit belongs to the family Cactaceae which includes genus *Selenicereus* and *Hylocereus*. Four commercially cultivated varieties of dragon fruit include *Hylocereus undatus* (Red peel and white pulp), *Hylocereus monacanthus* (Red peel and red pulp), *Hylocereus costaricensis* (Red peel and violet red pulp) and *Hylocereus megalanthus* (Yellow peel and white pulp). Due to its increase in demand in international markets it a high-potential crop for tropical and subtropical

regions. The former 3 species of dragon fruit are diploid (2n=2x=22) and the latter is tetraploid (2n=4x=44). Dragon fruit plants start bearing fruits 2-3 years after planting. Therefore, to understand the fruiting process it is important to know the flowering of the plant.

Alternating wet and dry seasons with more sunshine and rainfall of 600-1300 mm is the prerequisite for the production of dragon fruit. It is progressively attaining interest all over the world due to its tolerance to dry environments, resistance to diseases, flesh suitability and increasing demand around the world. The health conscious consumers prefer it due to the antioxidant properties known as "betalain". Now a day, it is known as "Healthy Food for the Table," due to the presence of low calories and more minerals and fibres. In natural conditions, it produces fruits in summer and fall as it is a long-day plant. There was some research on off-season pitaya or dragon fruit production in certain tropical areas such as Taiwan, Vietnam and Thailand have confirmed artificial lighting and/or growth stimulators regulate flowering in dragon fruit. Several researchers found that the effective treatment for off-season dragon fruit production was four-hour lighting 22:00 pm to 2:00 am with 75-100 W Tungsten filament.

During winter, night-breaking alone cannot ensure consistent off-season pitaya production as flower formation is influenced by the day length–temperature interaction (Chu and Chang, 2020). Khaimov-Armoza et al. (2012) found that long days (19/5 h light/dark) with suitable day/night temperatures (28 °C/22 °C) are vital for year-round *H. undatus* flowering. Chu and Chang (2020a) noted that white-fleshed pitaya floral bud development started at a LD length (14/10 h light/dark) when temperature exceeded 29 °C/19 °C (optimal temperature: 32 °C/22 °C), although red-fleshed pitaya may require lower temperatures (Chang, 2022).

Flowering (Flower initiation to Flower development)

Once the plants attain maturity, they begin to flower when the photoperiod exceeds 12 hours a day and the temperature ranges from 20-30 °C. This is true for species such as *Hylocereus undatus*, *H. monacanthus* and *H. costaricensis*. However, when the temperature rises above 40 °C, it is harmful to these plants, causing flower abortion and sunburn damage. However, in *Hylocereus megalanthus* the flowering begins with the onset of winter, during fall. The flower bud formation on dragon fruit plants occurs on areoles, terminally or laterally on the cladode. It takes around 2-3 weeks from flower bud formation to anthesis. The period varies depending upon the species, variety and region, which influence factors such as temperature, humidity and photoperiod (Jiang et al., 2012).

In India, the flowering pattern of dragon fruit mirrors the arrival of the monsoon across different states. Flowering in dragon fruit plants starts in the southern regions and gradually moves to northeastern states, followed by eastern, central, and western states and finally the northern parts of the country. The process of anther dehiscence, where pollen is released from the anthers, starts 3-4 hours before the flower opens (at around 10 p.m.) and continues till 2 a.m. early morning. The stigma becomes receptive with the opening of the flower and remains receptive for 11-12 hours, until the flowers close (Weiss et al., 1994). This timing is crucial for successful pollination and fruit development. In dragon fruit, flowering occurs in 4-7 cycles during summer. Typically, the fruit from the previous cycle matures around the same time as the flowers of the next cycle are blooming. The flower is nocturnal which means that the key process- anthesis (flower opening), anther dehiscence (pollen release) and pollination in flower occur at night. The flowers begin to open around 8 p.m and are fully opened by around 10 p.m. The pollination is carried out by nocturnal pollinators like fruit bats, hawk moths and flies.

Off-season flower production:

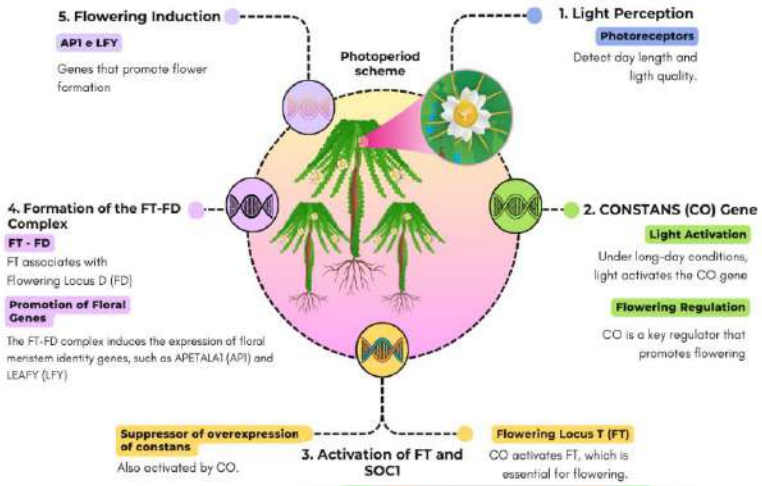
For the year-round production of dragon fruits, off-season flower production can be induced in dragon fruit plants. As dragon fruit is a long-day plant and its critical daylength requirement is 12 hours so night-breaking treatment is required from September to March for off-season fruit production. The period of the night-breaking treatment depends on the temperature of the region (Jiang et al., 2012).

Importance of light

Dragon fruit is a photoperiodic plant that optimally blooms in the geographic condition in which daytime is longer than night time. The main cropping season of dragon fruit spans from March to September in the following year and cultivation in the remaining period of the year should be aided with artificial irradiation during night time.

Pitaya flowers typically open at night between 7:00 p.m. and 9:00 p.m. and remain open until sunrise (7:00 a.m. to 9:00 a.m.), lasting about 9 to 14 h. Off-season flowering and fruiting stages tend to extend by 1 to 4 days compared to the primary flowering season. Low winter temperatures further prolong reproductive process. Currently, high-power incandescent lamps with capacity ranging from 75 W to 100 W are widely used to provide irradiation for 4–6 hr per night to dragon fruits. Incandescent light bulbs with capacity ranging from 75 W to 100 W are

also recommended by Vietnamese Ministry of Agriculture and Rural Development (MARD) to provide around 10 hr of artificial lighting per night.



(Source: Luíz Guilherme et al., 2025)

These photoperiod fluctuations underscore the importance of artificial light strategies, particularly LED technology, to mitigate seasonal limitations. Artificially extending day length allows pitaya producers worldwide to induce off-season flowering. Off-season pitaya production can be achieved by providing at least four hours of night time light (Chu and Chang, 2020). Flowering is governed by multiple biochemical and genetic pathways, such as those regulating photoperiod, vernalization, and gibberellic acid. Flower formation in plants encompasses three main stages: floral induction, floral evocation, and floral development. These pathways respond to signals that regulate the timing of flowering, with the photoperiod pathway, in particular, responding to day length and light quality. Figure 1 illustrates a simplified model of the molecular mechanisms involved in this process. Under long-day conditions, the CONSTANS (CO) gene acts as a key regulator, activating FLOWERING LOCUS T (FT) and SUPPRESSOR OF OVEREXPRESSION OF CONSTANS 1 (SOC1). The FT protein subsequently forms a complex with FLOWERING LOCUS D (FD), which promotes the expression of floral meristem identity genes such as APETALA1 (AP1) and LEAFY (LFY), thereby inducing flowering (Pan et al., 20104). Nighttime flowering in pitaya can be stimulated and intensified through light supplementation, which provides photosynthetically active radiation. This method has emerged as an attractive strategy for farmers to enhance main-season productivity and produce pitayas during the off-season. Among the most promising approaches are light-emitting diodes (LEDs), which emit little to no heat, unlike conventional lamps (Wallace and Both, 2016). The light

emitted by LEDs mainly depends on the semiconductor materials used, covering wavelengths from 250 nm to over 1,000 nm. Additionally, LEDs are more durable, compact, and cost-effective, offering both economic and environmental advantages over incandescent, fluorescent, and halogen lamps[45] . A technological approach involving artificial lighting during the off-season in southern Taiwan showed that red-fleshed pitaya responded better than white-fleshed pitaya, requiring extended illumination from 33 up to 48 d. This practice also led to increases in fruit mass and soluble solids content (Tran and Yen, 2014).

Conclusion

The study of dragon fruit flowering is an important aspect of the effective production of the crop and production of new varieties. The flower life commences with the production of reproductive buds on the cladode margins and ends with the wilting of flowers after pollination after which fertilization takes place and the fruit is produced. It takes 2-3 weeks from flower bud formation to pollination and the production of fruit is dependent on this period. Fruit bats and Hawk moths are the pollinators that aid in the cross-pollination of the flower. Summer season is the main dragon fruit flowering season but flowering can even be induced in winters by inducing night-breaking treatment. There are several problems in dragon fruit flowering such as self-incompatibility, self-sterility etc. which are needed to be taken care in future new varieties need to be developed which overcome these problems. Ultimately, light supplementation represents a sustainable and innovative tool to improve the efficiency, resilience, and competitiveness of tropical fruit production. Its thoughtful application can not only support food security and functional nutrition but also strengthen the economic viability of small- and medium-scale producers, particularly in regions constrained by seasonal limitations.

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EMO (EFFECTIVE MICROORGANISM) COMPOSTING TECHNOLOGY AND IT'S BENEFITS

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Introduction

EMO composting, also known as Bokashi composting, is a method of composting that uses effective microorganisms (EMOs) to accelerate the decomposition of organic waste. It's particularly well-suited for indoor composting or areas where space is limited. EMOs, like those found in Bokashi bran, help break down food scraps and other organic materials into a nutrient-rich fertilizer.

EM origin

In 1982 Dr.Higa at the University of Ryukyus, Okinawa Japan, discovered a specific group of naturally occurring beneficial microorganisms with an amazing ability to revive, restore, and preserve.He named this group E.M.(Effective microorganisms).

EM the natural product

- EM is the trade mark used to identify this particular mixture of beneficial organisms
- E.M. is a combined culture of aerobic microorganisms (requiring oxygen to survive) and anaerobic (requires no oxygen to survive) that co-exist together to the mutual advantage of both (symbiosis).
- E.M combines with the existing microorganisms within the soil. They work together to build a healthy living soil.
- E.M is not toxic or pathogenic and is safe for humans, animals and the environment.

EM solution mixing

Select a suitable sized container for mixing, some plastic bottles with caps for storage and a funnel. Add the molasses to the warm water and stir till thoroughly mixed. Then add the vinegar, whiskey and EM concentrate. Pour the mix into the plastic bottles and add small

quantities of chopped garlic etc. Seal as tightly as possible and leave in a warm dark place. Release any gas produced at least twice daily by releasing the cap. The EM is ready for use when the production of gas has stopped and the product has a sweet fruity smell. The mix can be stored in a dark cool place which has a uniform temperature for up to 3 months. If garlic extract has been used, filter this out before storage. Do not store in the refrigerator.

Warm water	300 ml
Molasses	50 ml
Natural vinegar	50 ml
Ethyl alcohol	50 ml
EM liquid conccentrate	50 ml



Where to use EM

Liquid

Concentrate

EM Liquid Concentrate can be used as a pre planting treatment, as a foliar spray, or for actively growing fruit and veggie crops, and for all ornamental plants. In fact anywhere in the garden including your compost heap or areas of poor or stagnant soil.

Applying EM Liquid Concentrate

Use EM liquid concentrate in the garden at the rate of 5ml EM concentrated solution diluted in 1 litre of clean chlorine free water. Apply at the rate of one litre per square metre. These are minimum recommended rates for use.

EM effect on soils and crops

The raw materials for compost production are:

- Rice straw
- Farmyard manure
- Urea fertilizer
- EM solution

Procedure

in layers of 20 cm height, 1 m width, and 5 m length to form a pile. A unit pile is about 5 m (length) × 1 m (width) × 1 m (height) in size. The pile is sprinkled with water for adequate moisture content, followed by addition of a manure layer 5 cm high, and the sprinkling of a few

handfuls of urea (100-200 g). EM solution, prepared as described before, is sprinkled to accelerate aerobic decomposition. This procedure is repeated until the pile is about 1 m high and then it is covered with a plastic sheet. The pile is turned after two weeks and then again after another week. Normally, the compost is ready two weeks later when the heap has cooled down and the height of the pile has fallen to about 70 cm.

EM effects on soils and crops

EM has been used on many different soils and crops over a wide range of conditions. Results show that in most cases EM gives positive results. EM is not a substitute for other management practices. EM technology is an added dimension for optimising our best soil and crop management practices such as crop rotations, use of composts, crop residue recycling, and biological control of pests. If used properly EM enhances soil fertility and promotes growth, flowering, fruit development and ripening in crops. It can increase crop yields and improve crop quality as well as accelerating the breakdown of organic matter from crop residues.The population of beneficial micro- organisms in the soil is also increased helping to control soil diseases through competitive exclusion. In New Zealand EM has Bio-Gro certification as an "Approved organic product".

How EMO Composting Works:

EM Inoculation:

EM is applied to the compost pile to introduce beneficial microorganisms that can break down organic matter more effectively.

Improved Decomposition:

EM can accelerate the composting process, leading to faster decomposition of organic waste and the production of higher-quality compost.

Nutrient Enhancement:

EM can also improve the nutrient availability in the compost by breaking down organic matter and releasing nutrients into a form that plants can readily absorb.

Odour Control:

EM can help to control odors by consuming volatile organic compounds that contribute to unpleasant smells during composting.

Humification:

EM can also contribute to the humification process, which involves the formation of stable humus in the compost, which is beneficial for soil health and plant growth.

Benefits of EMO Composting:

Faster Composting:

EM can shorten the time it takes to produce usable compost.

Higher Quality Compost:

EM can produce compost that is richer in nutrients and more beneficial for plant growth.

Reduced Odors:

EM can help to control odors and make composting a more pleasant experience.

Improved Soil Health:

EM can contribute to the formation of stable humus, which is beneficial for soil health.

Applications of EMO Composting:

Home Composting:

EMO can be used in home composting systems, such as Bokashi bins, to accelerate decomposition and improve compost quality.

Large-Scale Composting:

EMO can be used in larger composting facilities to improve the efficiency and quality of compost production.

Agriculture:

EMO can be used in agriculture to improve soil health and enhance plant growth.

Disadvantages of EMO Composting:

Requires Digging:

EMO composting often involves digging holes to bury waste, which may not be practical or suitable for all composting situations or if you want to collect and use the compost later.

Slow Decomposition:

Once buried, EMO composting can be slow to decompose.

Limited Waste Types:

Some EMO systems might not be able to compost all types of kitchen waste.

Odor:

Some EMO-based mechanical composting systems can create an earthy odor in the house.

Potential Pests:

If not properly managed, compost piles can attract pests like house flies.

Maintenance:

EMO-based mechanical systems can be tricky to clean and maintain.

Cost:

Mechanical composting systems can be expensive to purchase.

Electricity Requirement:

Some mechanical composters require electricity to operate

Conclusion

EM composting offers a powerful and sustainable approach to waste management and soil enrichment.

By leveraging the power of beneficial microorganisms, this process can accelerate decomposition, enhance compost quality, and contribute to a more environmentally friendly and efficient waste management system.

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FROM SILK PRODUCTION TO FOOD ADDITIVES: REPURPOSING SILKWORM EXCRETA

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Abstract

Silkworm excreta (frass), a byproduct of sericulture, have emerged as a promising natural thickener with significant potential for sustainable applications in the food and pharmaceutical industries. This review examines the scientific basis for its thickening properties, focusing on its high dietary fiber content (30–45%) and pectin-like polysaccharides that exhibit excellent water-binding and gelling capacities. We analyze comparative performance against conventional thickeners (xanthan gum, agar), highlighting frass's advantages in thermal stability (up to 80°C) and prebiotic fiber content. Current applications span plant-based dairy alternatives, sauces, and biodegradable packaging, while emerging research explores its pharmaceutical potential via bioactive compound extraction. Despite its promise, challenges persist in flavor neutralization, regulatory approval, and consumer acceptance. We propose strategies to address these barriers, including enzymatic refinement and chef-driven gastronomic applications. By integrating findings from patents (e.g., CN104012764A) and recent studies on optimized extraction methods, this article positions silkworm frass as a model for circular economy innovation in the functional ingredients sector. The path forward requires interdisciplinary collaboration to transform this underutilized resource into a mainstream sustainable solution.

Keywords: silkworm frass, natural thickener, circular economy, sustainable food additives, sericulture byproducts

Introduction

For centuries, silkworms have been valued for their luxurious silk, but their discarded frass (excrement) has largely been treated as agricultural waste. Now, researchers are discovering that this natural byproduct contains unique fibers and compounds that could revolutionize food texture offering a **plant-based, eco-friendly alternative** to conventional thickeners like gelatin or xanthan gum. From improving the mouth feel of dairy-free yogurts to stabilizing sauces without artificial additives, silkworm frass could help solve some of the food industry's biggest challenges. But can something once considered waste really become a kitchen staple? This article explores the science, benefits, and hurdles behind this unexpected ingredient—and whether it could soon make its way into our food. While challenges remain, this innovation could turn waste into worth, aligning with today's demand for **eco-friendly food solutions**.

The Science behind Silkworm Frass as a Natural Thickener

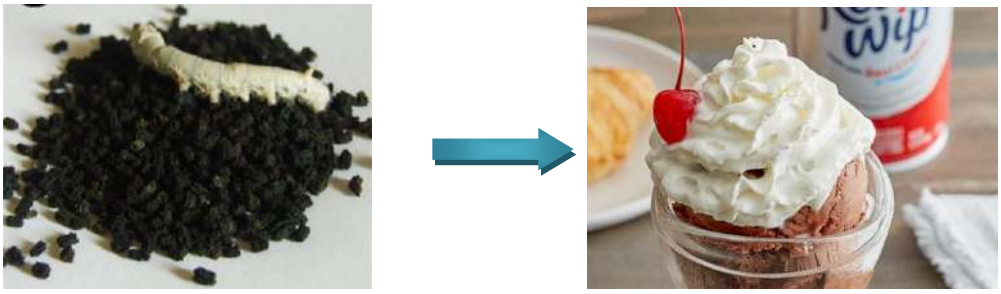
Recent research has revealed that silkworm frass (excrement) possesses remarkable thickening properties, making it a promising natural alternative to conventional food thickeners. This unexpected functionality stems from its unique composition - containing 35-50% dietary fiber from partially digested mulberry leaves along with pectin-like polysaccharides. When mixed with water, these components work together through three key mechanisms: the fibers absorb 3-5 times their weight in water, the polysaccharides form gel-like networks, and the dry particles swell significantly.

Compared to common thickeners, silkworm frass offers several advantages. It provides more dietary fiber than xanthan gum, better heat stability than cornstarch, and comes from a completely natural source rather than synthetic production. Recent studies have shown that a 1% frass solution can achieve viscosity comparable to 0.5% xanthan gum, with composting treatment enhancing its thickening capacity by 20-30%. Initial tests suggest potential applications in sauces, dressings, and baked goods.

The use of silkworm frass presents an innovative example of circular economy in food production, transforming waste into value. As a thickener, it not only improves texture but also adds nutritional fiber absent in most conventional options. However, challenges remain in processing to remove natural color and flavor, and regulatory approval is still pending in most markets. Current research focuses on optimizing extraction methods, expanding food applications, and pursuing necessary certifications. With further development, this sericulture

byproduct could provide the food industry with a sustainable, plant-based thickening solution while reducing reliance on synthetic additives.

Ongoing studies continue to explore the full potential of this remarkable natural resource, which may soon find its way into various food products as consumers increasingly demand cleaner labels and more sustainable ingredient.



Potential Applications of Silkworm Frass as a Natural Thickener

Food Industry Applications

Silkworm frass shows exciting potential as a sustainable thickener in various food products. In sauces and dressings, its water-binding capacity and shear-thinning properties allow it to create smooth, stable textures without the need for synthetic additives like xanthan gum. The high fiber content from undigested mulberry leaves makes it particularly valuable for plant-based dairy alternatives, where it could improve the mouthfeel of vegan yogurts and cheeses while adding nutritional benefits. As a low-calorie, high-fiber additive, silkworm frass could help manufacturers meet growing consumer demand for clean-label ingredients that support digestive health. Early research suggests it may also work well in gluten-free baked goods, where its moisture retention properties could address common texture challenges.

Non-Food Applications

Beyond the food industry, silkworm frass has promising uses in cosmetics and packaging. In lotions and creams, its polysaccharides could serve as natural stabilizers, replacing synthetic emulsifiers while potentially offering additional skin benefits from the nutrient-rich mulberry leaf compounds. The biodegradable nature of frass also makes it an attractive candidate for eco-friendly packaging films, where its fibrous structure could help create edible or compostable materials. This aligns with the increasing push toward circular economy solutions in manufacturing, turning what was once considered waste into valuable, functional materials.

Benefits: Why Even Consider Silkworm Frass?

Sustainability Advantages

Silkworm frass offers a compelling solution to two major environmental challenges. First, it provides a productive use for what was previously considered waste in silk production, reducing pressure on landfills and creating new value from sericulture byproducts. Second, its production requires significantly less energy and resources compared to synthetic thickeners like carboxy methylcellulose, resulting in a lower carbon footprint. Life cycle analyses suggest that utilizing frass could reduce the environmental impact of food additives by up to 40% when considering factors like water usage and greenhouse gas emissions. This makes it particularly attractive for companies looking to improve their sustainability profiles while maintaining product quality.

Nutritional Benefits

Beyond its functional properties, silkworm frass brings unique nutritional advantages to food formulations. The prebiotic fiber content derived from undigested mulberry leaves may support gut health by promoting beneficial bacteria growth - a feature completely absent in most conventional thickeners. Additionally, early analyses indicate the material retains valuable minerals from its mulberry leaf diet, including iron and potassium, which could contribute to the nutritional profile of fortified foods. Unlike nutritionally inert synthetic thickeners, frass offers the potential to enhance both texture and nutritional value simultaneously, creating opportunities for multifunctional clean-label products. These characteristics make it particularly relevant for the growing market of health-conscious consumers seeking foods with added functional benefits.

Challenges & Controversies of Using Silkworm Frass as a Food Thickener

1. Taste & Texture: Overcoming the "Earthy" Factor

Silkworm frass has a distinct **earthy, roasted flavor** with notes of tobacco and popcorn when processed, which may limit its use in neutral-flavored foods like dairy alternatives or baked goods. While roasting can enhance desirable flavors (e.g., caramelization at 160°C for 40 minutes), it may also introduce **fishy or hay-like off-notes** derived from mulberry leaves, requiring additional refinement. Texture-wise, frass thickeners can create a **smooth but slightly granular** mouth feel compared to synthetic options like xanthan gum, which may affect consumer acceptance in premium products

2. Safety & Regulation: Navigating Legal Hurdles

- **GRAS Status**: Silkworm frass is **not currently GRAS-certified** in the U.S., though similar insect-derived ingredients (e.g., cricket flour) have gained approval.
- **EU Approval**: Under the EU Novel Food Regulation (2015/2283), insect-based products require case-by-case authorization. As of 2025, silkworm frass lacks specific approval, unlike yellow mealworm or house cricket derivatives
- **Asia**: In China and Thailand, silkworm byproducts (e.g., pupae) are traditionally consumed, but frass as a food additive remains understudied.

3. Consumer Psychology: The "Yuck" Factor

- **Cultural Barriers**: Western consumers often associate insect-derived ingredients with contamination, despite their historical use in Asian cuisines (e.g., Korean silkworm soup).
- **Marketing Strategies**: Framing frass as a **"sustainable superfood"** or leveraging fine-dining endorsements (e.g., Alchemist restaurant's frass tea) can shift perceptions.
- **Labeling Transparency**: Surveys suggest **58% of EU consumers reject insect-based foods**, highlighting the need for clear communication about sourcing and benefits

The Future – Is Silkworm Frass a Realistic Solution?

Ongoing Research & Innovation

Universities and startups are actively investigating methods to optimize silkworm frass extraction and application:

- **Extraction Techniques**: Research focuses on **enzymatic hydrolysis** and **ultrasonic-assisted methods** to improve yield and purity while reducing energy consumption . For example, studies at Zhejiang Academy have identified microbial enzymes (e.g., *Klebsiella pneumoniae*) in composted frass that enhance gelling properties.
- **Flavor Masking**: Roasting (160°C for 40 minutes) reduces earthy notes and unlocks desirable flavors like roasted corn or tobacco, as demonstrated in gourmet tea experiments.
- **Regulatory Progress**: While not yet GRAS-certified, silkworm-derived products are gaining traction in Asia, with China exploring approvals for food-grade applications.

Market Potential vs. Algae-Based Thickeners

Silkworm frass could carve a niche in the **$1.2B natural thickener market**, but challenges remain:

Factor	Silkworm Frass	Algae-Based Thickeners
Cost	Lower production costs (waste upcycling)	Higher (requires controlled farming)
Sustainability	Zero-waste, circular economy appeal	Water- and energy-intensive
Functionality	High fiber, prebiotic benefits	Neutral flavor, wider acceptance
Scalability	Limited by silk farm output	Established supply chains

Algae still dominate due to **consumer familiarity** and **regulatory clarity**, but frass's **nutritional edge** (e.g., iron retention from mulberry leaves) could appeal to functional food markets.

Expert Perspective

Dr. Nabila Rodríguez Valerón, a gastronomic scientist who studied silkworm frass tea at the Basque Culinary Center, notes: "The fine-dining sector is a gateway for unconventional ingredients. When Alchemist [a Michelin-starred restaurant] served our frass tea, perceptions shifted overnight. Scaling this requires solving two puzzles: streamlining production and framing frass as a premium, sustainable choice—not just 'bug waste.'"

Conclusion

Silkworm frass represents an innovative solution in the search for sustainable food thickeners, offering both environmental and functional benefits. As a byproduct of silk production, it provides a circular economy approach by transforming waste into value. The material's natural thickening properties, derived from its high fiber content and gelling polysaccharides, show promising performance comparable to conventional thickeners. Beyond functionality, it brings nutritional advantages including prebiotic fiber and retained minerals from mulberry leaves. Several challenges must be addressed for commercial viability. Technical refinements are needed to optimize extraction processes and ensure consistent quality.

Regulatory pathways require clarification, particularly in Western markets where insect-derived ingredients face stricter scrutiny. Perhaps most significantly, consumer acceptance strategies must overcome the psychological barrier of using insect byproducts in food. Market introduction through premium or specialty products may help establish credibility before mainstream adoption.

The growing demand for sustainable, clean-label ingredients creates favorable conditions for silkworm frass adoption. With continued research and strategic industry collaboration, this unconventional resource could emerge as an important tool in developing more sustainable food systems. Its success will ultimately depend on balancing scientific potential with practical considerations of production, regulation, and consumer perception.

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INDIA'S SILK TRAIL: GI TAGS THAT PROTECT THE PRIDE OF SERICULTURE

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Abstract

India is globally recognized for its rich and diverse silk traditions, many of which are deeply rooted in regional culture, ecology, and craftsmanship. Geographical Indication (GI) tags serve as legal identifiers that protect and promote these unique silk varieties by certifying their origin and authenticity. This article explores prominent GI-tagged silks across various Indian states, including Muga and Eri silks from Assam, Kanchipuram and Arani silks from Tamil Nadu, Mysore silk from Karnataka, and Chanderi, Baluchari, Murshidabad, and Banarasi silks from central and northern India. Each of these silk types reflects distinctive weaving styles, raw material sources, and cultural narratives. GI tagging not only ensures quality and authenticity but also safeguards traditional weaving communities from economic exploitation and imitation. While challenges such as counterfeit products and limited public awareness persist, the implementation of advanced traceability systems and promotional initiatives can enhance the sustainability and global recognition of India's silk heritage.

Introduction

India has long held a distinguished place in the global silk industry, not only as one of the leading producers of silk but also as a cradle of diverse regional silk traditions deeply rooted in its socio-cultural fabric. From the golden hues of Muga silk in Assam to the opulent Banarasi brocades of Uttar Pradesh, silk in India transcends mere fabric—it embodies a narrative of heritage, identity, and craftsmanship. These silks are intrinsically tied to specific agro-climatic

conditions, local biodiversity, and centuries-old artisanal practices passed down through generations. However, in an era of globalized markets and mass production, these unique identities face increasing threats from imitation products and diminishing traditional livelihoods. To counter these challenges and to safeguard India's intangible textile heritage, the Geographical Indication (GI) tag system, under the purview of the Geographical Indications of Goods (Registration and Protection) Act, 1999, has emerged as a powerful legal tool.

GI tags serve as intellectual property rights that protect products which possess specific qualities, reputation, or characteristics attributable to their geographical origin. Within the context of sericulture, GI tags authenticate the origin of traditional silk varieties and ensure that only producers within the designated regions are legally permitted to use the protected name. This mechanism not only fosters product integrity and consumer trust but also enhances market competitiveness and rural economic resilience.

This article explores the significance of GI tagging in Indian silk, highlighting major GI-registered silk varieties across states, and examining how this certification contributes to preserving traditional knowledge systems, supporting artisanal livelihoods, promoting cultural tourism, and ensuring sustainable economic development.

What is a Geographical Indication (GI) Tag?

GI tag is a legal which is awarded to those products which have certain qualities, characteristics or reputations that are in-effect, attached to a geographic region in which the products are produced. Within the interest of sericulture, GI labels are issued to specific types of silk that attained its popularity as a result of hundreds-years-old traditions of rearing and weaving. In addition to avoiding any misappropriation of the regional name, this certification will facilitate the value addition concerning the product in the market and its appreciation by consumers.

Significance of GI Tags in the Silk Industry

In case of silk industry, GI tagging can be highly helpful in terms of cultural identity as well as helping the rural artisans. It contributes in marketing of the regional silks in both the local and abroad market making it more competitive. The GI label also guarantees price premium to the authentic producers, an incentive to promote conventional craft work and a disincentive to mass-market imitation. In addition, GI status encourages tourism and increases the value of narration behind the product.

Muga Silk – Assam: Nature's Golden Thread

The Assamese silk is known as muga and is unique of its kind; is thus referred to as the golden treasure of India owing to the natural lustrous golden-yellow tone which it maintains without any dyeing. The Antheraea assamensis silkworm produces this silk and only the special climatic conditions and flora of the Brahmaputra valley makes it possible to grow. Muga silk is a heritage product famous by its ability to stay long when subjected to washing, and the shine of its fabric grows every time it is washed.

Traditional Assamese garments such as mekhela chadors weaved commonly and exclusively using this are one of the few clothes that GI tag guarantees you will not find this being made of any other type of silk except silk made in Assam and that the name Muga cannot be made of any other type of silk other than this one.

Eri Silk – Assam: The Ahimsa Silk of the East

Eri Silk is not only native to Assam and the Northeast region of India but also well known as the so-called Eri silk, meaning one which is not killed after gathering the silk; the so-called Ahimsa silk. Being produced with the help of the Samia ricini silkworm, which uses mainly castor leaves as a power source Eri silk is soft, warm and very breathable which makes it a perfect summer and winter clothing. In comparison to other silks, Eri is spun similarly to cotton like and sports a matte finish, giving the wool-like look. It is utilized in producing shawls, stoles and scarves and is being embraced in its sustainability and ethical fashion practices. GI marking of Eri silk is contributing to conservation of traditional customs and enable the tribal people who depend on it to earn a living.

Kanchipuram Silk – Tamil Nadu: The Temple-Weave Legacy

The Kanchipuram silk of the town of Kanchipuram, Tamil Nadu, is amongst the most luxurious kinds of silks in India, especially sarees worn in weddings and at temples. The silk received consists of fine mulberry silk threads and fine zari threads which have silver and gold. Old style Kanchipuram sarees have contrast borders, heavy pallus and temple-nature epics designs. GI tag makes sure that this fine work is limited to the area. We are not only selling a saree when we give you a Kanchipuram, we are actually selling a tradition of art and religious mark.

Arani Silk – Tamil Nadu: The Unsung Jewel of Light Silk

Arani silk sarees are made in Arani area of the Tiruvannamalai district of the state of

Tamil Nadu and are very light, shiny and colorful. They are traditionally constructed with good mulberry silk and are preferred by their comfort and cheapness, which makes them better to be used in everyday life stuff and small ceremonies. Compared to the heavier Kanchipuram saree, Arani silks are usually preferred due to their light weight and their portability. This less popular and yet the culturally important silk has seen the light of the market through the GI tag recognition which has enabled its local weavings to get fair access of the market, as well as recognition of their inherent skilled handloom work.

Mysore Silk – Karnataka: A Royal Weave with a Serial Code

Silk Mysore-produced by the Karnataka Silk Industries Corporation (KSIC) has an extraordinary smooth texture, which makes it very velvety in appearance and also it is very delicate. The difference between Mysore silk and other types is that it is certified by the government with the proper production process and eco-friendly dyes as well as the use of pure gold zari. Every saree is designed to have a special code serial number and a hologram to ensure originality. Mysore silk has always been a minimal luxurious piece that was worn by royal people and temple dancers. GI tag prevents misuse of this treasure trove and only the silk made using ancient and traditional methods in Mysore should be allowed to use the name which brings further reputation and market valuation.

Chanderi Silk- Madhya Pradesh: A Marvel of Sheer

Chanderi (silk) Chanderi a town in the State of Madhya Pradesh, is a mix of silk and cotton or pure silk, with a light and sheer quality, and glossy transparency. Sarees made of Chanderi using centuries old methods, are the usual uses of the Chanderi sarees, and usually have motifs of peacocks, lotuses and coins. It is perfect in hot weather of India and so it is popular during summers and ceremonial occasions. GI tag is useful in guarding the authenticity of the weaves of Chanderi and the artificial machine-made replicas which can ultimately negate the tradition of the handloom art. The Chanderi story is not only a cloth story-it is a story of existence of the soul of a community.

Baluchari Silk- West Bengal: Epic Tales as Woven on the Loom

The West Bengal Baluchari silk sarees are found to be unique with their story designs weaved in their borders and pallus thematically describing incidents found in Indian mythology like Ramayana and the Mahabharata. These sarees are created with the use of luxuriously stained mulberry silk fiber threads and traditionally they are worn by aristocratic ladies in Bengal.

Weaving industry was most successful in the town of Baluchar, and shifted to Bishnupur. The GI tag has played an instrumental part in revitalizing this dying art form and urging the new generations to pick up the art and continuing the tradition of story telling that combines textile with history and folklore.

Murshidabad Silk West Bengal - The Wonder Light Fabric

The other silk sold in West Bengal that is characterized by fine thread, smooth finish, very light weight is the Murshidabad silk. It is used perfectly in hand painting, block printing, as well as screen printing hence so much-preferred by the designers and artists. Murshidabad silk is used to make sarees, both light to wear on a day to day basis, yet rich enough to wear during special occasions. They are very versatile though not as ornate as Baluchari.

Banaras Brocades & Sarees – Uttar Pradesh: Regal and Resplendent

The elaborate brocade work in gold and silver threads, known as zari, is what makes Banaras or Varanasi silk sarees famous worldwide. North Indian bridal trousseaus would not be complete without these opulent, heavy sarees. Floral butas, Mughal-inspired designs, and intricate weaving methods like katan, tanchoi, and jamdani are examples of traditional patterns. In addition to supporting the thousands of weavers in Varanasi who continue to preserve the tradition of royal Indian weaving, the GI tag for Banaras silk helps shield this age-old craft from mass-produced imitations.

Surat Zari Craft – Gujarat: Threads of Shimmer and Shine

Gujarat's Surat is well known for producing zari, or metallic thread, which is widely used in Indian textiles and silk sarees. Real and fake zari made from copper, gold, or silver wires wound with silk or polyester threads are included in the GI-tagged Surat Zari Craft. These threads are necessary for adorning national and local silk fabrics, such as Kanchipuram, Paithani, and Banarasi. One of the biggest weaving communities in India is protected by the GI status, which guarantees that only zari made in Surat using traditional techniques may bear the name.

Silk Variety	State/Region	Specialty
Mysore Silk	Karnataka	Known for its high-quality mulberry silk and rich zari work.
Kanchipuram Silk	Tamil Nadu	Famous temple silk, hand woven with mulberry silk and gold thread.
Arani Silk	Tamil Nadu	Lightweight and fine silk sarees woven in Arani town.

Chanderi Silk	Madhya Pradesh	Blends silk with cotton, has sheer texture and intricate designs.
Banaras Brocades & Sarees	Uttar Pradesh	Richly woven with gold and silver brocade.
Baluchari Silk	West Bengal	Known for mythological scenes on pallu and borders.
Murshidabad Silk	West Bengal	Fine, lightweight silk ideal for printing.
Muga Silk	Assam	Golden yellow color, durable, exclusive to Assam.
Eri Silk	Assam	Also called "Ahimsa silk," known for its thermal properties.
Surat Zari Craft	Gujarat	Includes silk thread work in traditional zari weaving.

Challenges and the Way Forward

Notwithstanding their benefits, GI-tagged silks have drawbacks, including low consumer awareness, insufficient defense against fake goods, and disorganized marketing. Government backing, branding campaigns, and community education are necessary to fortify the GI ecosystem. Blockchain technology and digital certification may also aid in GI-tagged silks' integrity preservation and origin tracking.

Conclusion

The Geographical Indication system in India represents more than a legal safeguard—it is a cultural contract that binds the economic, ecological, and emotional identities of regions with their artisanal legacies. In the case of Indian sericulture, GI-tagged silk varieties such as Muga, Eri, Kanchipuram, Mysore, Baluchari, and others not only exemplify regional excellence in craftsmanship but also narrate stories of resilience, heritage, and localized knowledge systems. Through GI recognition, these silks are able to resist commodification and standardization, preserving their authenticity amidst growing threats from industrial imitations and synthetic alternatives.

Despite its achievements, the GI ecosystem in India still faces significant hurdles. These include limited public awareness about the value of GI tags, inadequate marketing infrastructure, lack of enforcement against counterfeit goods, and insufficient support to artisans for value addition and branding. To realize the full potential of GI-tagged silks, it is imperative to integrate modern tools such as blockchain traceability, QR-coded product verification, and digital

storytelling to engage contemporary consumers. Furthermore, collaborative efforts involving government bodies, local cooperatives, NGOs, and research institutions must be intensified to educate stakeholders, facilitate market access, and build inclusive supply chains.

Ultimately, when consumers choose GI-tagged silk, they are not merely buying a textile—they are investing in heritage, sustainability, and the hands that keep India's silk traditions alive. As India continues to promote its cultural and creative economy, the protection and promotion of GI-tagged silk will remain central to weaving a more inclusive and prosperous future for its rural artisan communities.

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NANOTECHNOLOGY IN SERICULTURE: A MODERN APPROACH TOWARDS SILK

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Abstract

Nanotechnology is transforming sericulture by introducing groundbreaking solutions that enhance productivity, sustainability, and economic viability across the silk production chain. In mulberry cultivation, nanofertilizers and smart nanopesticides increase yields by 30–40% while minimizing environmental harm through precision agriculture. For silkworm rearing, nanoparticle-enhanced feeds improve growth, disease resistance, and silk quality, replacing harmful chemical treatments. Beyond production, nanotechnology unlocks high-value applications such as antimicrobial textiles and biomedical materials positioning silk as a sustainable alternative to synthetic fabrics. However, responsible adoption requires scalable, farmer-friendly solutions, rigorous safety protocols, and supportive policies. By merging tradition with innovation, nanotechnology secures sericulture's future, ensuring its competitiveness in global markets while preserving ecological balance and cultural heritage. This technological leap promises a resilient, high-performance silk industry for the 21st century.

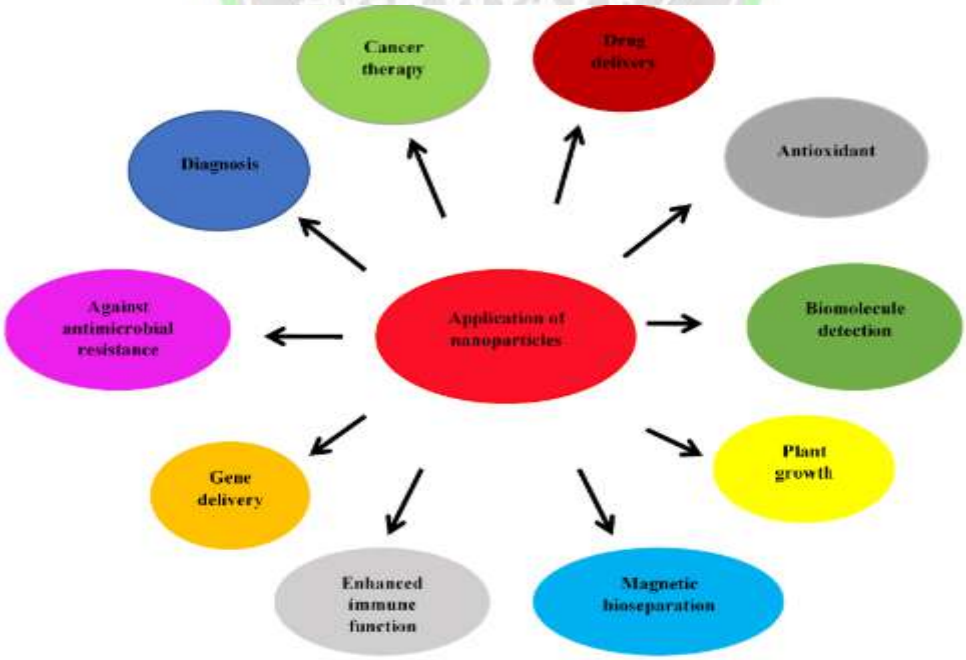
Introduction

Nanotechnology is the science, engineering, and application of materials and devices at the **nanoscale** (typically 1 to 100 nanometers). At this scale, materials exhibit unique physical, chemical, and biological properties that differ from their bulk counterparts, enabling novel applications across diverse fields. Nanotechnology has the potential to revolutionize industries by enabling smarter, more efficient, and sustainable solutions. In the context of **mulberry plants**

and silk production, it could enhance crop resilience, silkworm health, and silk quality through precision tools like nanofertilizers or disease-targeting nanoparticles. Nanotechnology holds significant potential to revolutionize **sericulture** (the cultivation of silkworms for silk production) by addressing key challenges and enhancing productivity, sustainability, and silk quality. Nanotechnology, the manipulation of matter at the atomic and molecular scale, has emerged as a revolutionary field with applications spanning medicine, energy, electronics, and agriculture. In recent years, its potential in enhancing agricultural productivity and improving livestock management has garnered significant attention. One area where nanotechnology holds immense promise is in sericulture—the cultivation of mulberry plants and rearing of silkworms for silk production. Sericulture is a vital agro-based industry, particularly in countries like India, China, and Brazil, providing livelihoods to millions of farmers and contributing significantly to the economy.

Why it matters

Nanotechnology has the potential to revolutionize industries by enabling smarter, more efficient, and sustainable solutions. In the context of mulberry plants and silk production, it could enhance crop resilience, silkworm health, and silk quality through precision tools like nanofertilizers or disease-targeting nanoparticles.



Challenges in Sericulture

Sericulture, the cultivation of silkworms for silk production, faces numerous challenges that threaten its sustainability and productivity. The agricultural challenges primarily revolve around mulberry cultivation, where soil degradation from continuous farming depletes essential nutrients, while water scarcity and inefficient irrigation systems hinder optimal growth. Pest and disease infestations further compromise leaf quality and availability, compounded by an increasing shortage of skilled labor due to rural-urban migration.

Biological challenges present significant obstacles, with silkworms being highly susceptible to devastating diseases like pebrine, flacherie, and muscardine, which can decimate entire batches. The species' inherent low immunity makes them vulnerable to environmental stressors, while prolonged inbreeding has led to genetic degradation, resulting in weaker strains with reduced productivity and disease resistance.

Environmental factors, particularly climate change, introduce unpredictable challenges through temperature fluctuations and erratic weather patterns that disrupt silkworm rearing cycles. Pollution from agricultural chemicals and industrial contaminants further jeopardizes both mulberry quality and silkworm health, creating additional barriers to consistent production.

Socio-economic hurdles include rising production costs that diminish profitability, while the industry's reliance on traditional methods limits efficiency gains. Market volatility and price fluctuations, driven by global competition and synthetic alternatives, create financial instability for farmers, exacerbated by limited access to modern training and technological advancements.

Technological and infrastructural limitations present further constraints, with inadequate research into improved silkworm breeds and mulberry varieties, coupled with insufficient storage and processing facilities that lead to post-harvest losses. These multifaceted challenges underscore the need for comprehensive solutions to ensure the future viability of this important agro-based industry.

Nanotechnology Solutions for Sustainable Sericulture

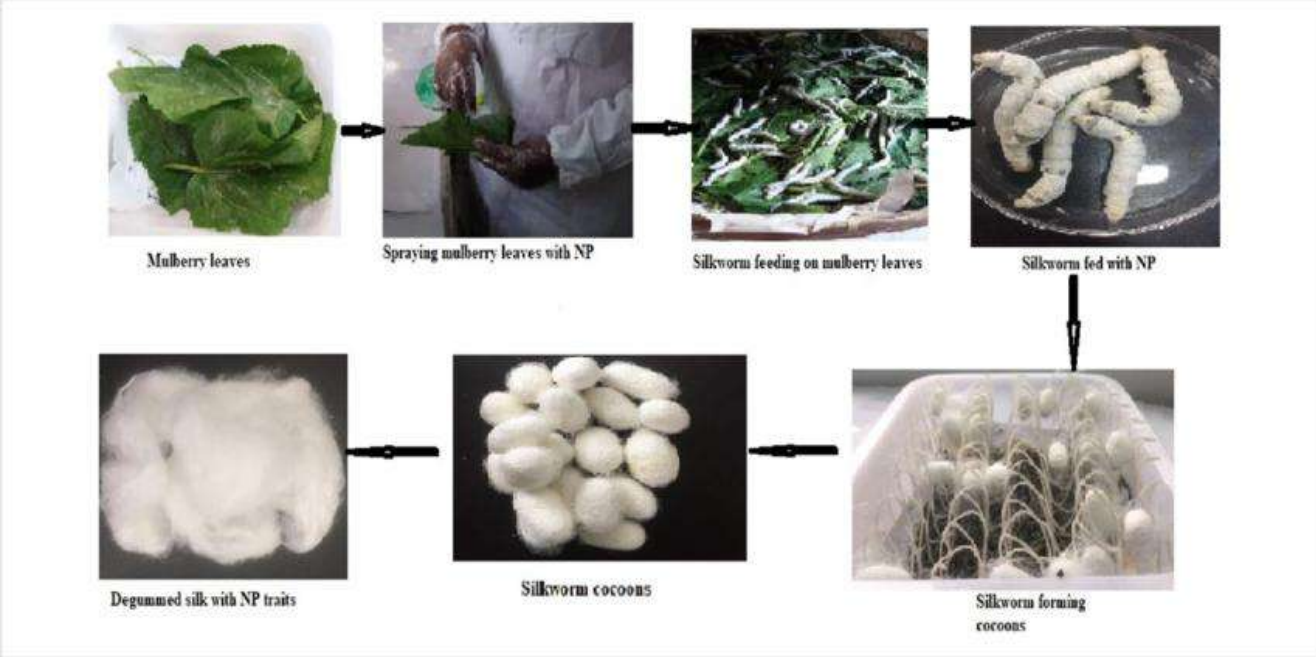
1. Enhancing Mulberry Cultivation with Nano-Enabled Agriculture

Nanotechnology offers transformative solutions for mulberry cultivation, addressing critical challenges in soil fertility, pest management, and stress tolerance. Nanofertilizers, engineered with precisely controlled nutrient release mechanisms, significantly improve mulberry leaf yield and quality while reducing environmental contamination. These advanced

formulations, including nitrogen-, phosphorus-, and micronutrient-based nanoparticles, enhance nutrient uptake efficiency and promote sustainable farming practices. Concurrently, smart nanopesticides utilizing silver and chitosan nanoparticles provide targeted protection against pathogens while minimizing ecological harm. Nanosensor networks enable real-time monitoring of soil health and plant stress, allowing farmers to optimize irrigation and nutrient management with unprecedented precision.

2. Optimizing Silkworm Health and Cocoon Production

The application of nanotechnology in silkworm rearing revolutionizes nutrition delivery and disease prevention. Nanoparticle-fortified feeds, incorporating elements like selenium, zinc, and silver, significantly enhance larval growth rates, immune function, and stress resistance. These nano-formulations improve nutrient bioavailability, leading to healthier silkworms with increased cocoon yields and superior silk quality. Furthermore, antimicrobial nanoparticles effectively combat common silkworm diseases such as pebrine and flacherie, reducing mortality rates without relying on traditional antibiotics. The integration of carbon-based nanomaterials in silkworm diets has demonstrated remarkable improvements in silk fiber strength and elasticity, opening new possibilities for high-performance textile applications.



3. Advancing Silk Processing and Value-Added Applications

Nanotechnology extends its benefits beyond production into silk processing and functionalization, creating innovative materials with enhanced properties. Nano-coatings of

silver and titanium dioxide impart antimicrobial and UV-resistant characteristics to silk fabrics, expanding their use in medical and technical textiles. In the biomedical field, silk-based nanocomposites reinforced with hydroxyapatite or graphene derivatives show exceptional potential for tissue engineering scaffolds and drug delivery systems. These advancements not only increase the commercial value of silk but also position sericulture as a key player in sustainable material science, bridging traditional practices with cutting-edge nanotechnology.

4. Towards a Sustainable and High-Tech Sericulture Future

The integration of nanotechnology across the sericulture value chain represents a paradigm shift in sustainable silk production. From precision mulberry farming to engineered silkworm nutrition and advanced silk processing, these innovations address critical challenges of productivity, environmental impact, and product quality. As research progresses, the synergy between nanotechnology and sericulture promises to enhance global competitiveness while preserving ecological balance, ensuring the long-term viability of this ancient industry in the modern era.

Challenges and Future Directions

While the potential of nanotechnology in sericulture is immense, several challenges need to be addressed to realize its full benefits. These include:

Safety and Toxicity:

The long-term effects of nanoparticles on mulberry plants, silkworms, and the environment are not fully understood. Rigorous studies are needed to assess the safety and toxicity of nanomaterials used in sericulture.

Cost and Accessibility:

The high cost of nanotechnology-based products may limit their accessibility to small-scale farmers. Efforts should be made to develop cost-effective and scalable solutions.

Regulatory Framework:

The lack of clear regulations governing the use of nanotechnology in agriculture poses a challenge. Policymakers need to establish guidelines to ensure the safe and responsible use of nanomaterials.

Conclusion

Nanotechnology is revolutionizing sericulture by offering innovative solutions across the entire silk production chain**.** In mulberry cultivation, nanofertilizers and smart nanopesticides

boost yields by 30-40% while reducing environmental impact through precise nutrient delivery and targeted pest control. For silkworm rearing, nanoparticle-enhanced feeds improve growth rates, disease resistance, and silk quality, offering eco-friendly alternatives to chemical treatments. Beyond production, nanotechnology enables high-value silk applications through functionalization - creating antimicrobial, UV-resistant fabrics and advanced biomedical materials. These innovations position silk as a sustainable alternative to synthetics in multiple industries.

While promising, responsible implementation requires scalable, affordable solutions for small farmers, rigorous safety testing, and clear regulations. The fusion of nanotechnology with traditional sericulture preserves cultural heritage while driving sustainable rural development. By bridging ancient practices with cutting-edge science, nanotechnology ensures sericulture's viability in the modern era - transforming challenges into opportunities for growth, sustainability, and global competitiveness.

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USE OF NEEM COATED UREA IN ENHANCING NITROGEN USE EFFICIENCY AND PREVENTING NITROGEN LOSS

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Introduction

The potential of Neem Coated Urea and its acceptance by the farmers, Ministry of Agriculture in July 2004, included Neem Coated Urea in FCO. The use of Neem Coated Urea has been found to improve the uptake of N, P and K significantly. Since 2008, Ministry of Chemicals and Fertilizers allowed Neem Coated Urea (NCU) manufacturer to sell NCU at 5% above the MRP mainly to recover the cost of coating, however cost of Neem kernel Oil and production of Neem Coated Urea has increased significantly. As per recent notification dated 25.05.2015 all the urea producers in country shall now be producing 100% urea as NCU in order to improve crop productivity and to reduce the subsidy on it.

Balanced use of N, P and K along with the requirements of secondary and micronutrient increase the yield at economic level. Among three major nutrients, nitrogen in nitrate will lost through the process of leaching and de-nitrification process.

Keeping in view the low Nitrogen use efficiency (NUE) it has been felt to find out the use of some indigenous use of material and coating processes for reducing the nitrogen losses from Urea. Use of Neem oil in various forms such as Neem oil cake, Neem oil and other Neem products have been found to be useful in reducing the release from Urea and increase its use efficiency. Neem oil contains various kind of bitter, especially the Meliacins that have been identified in retarding the process of nitrification of Urea.

Impact on soil fertility

Out of 17 essential plant nutrients, nitrogen (N) generally required in larger amounts for growth of plant. Urea is one of the most widely used sources of fertiliser N (46%) in the world. When urea applied to soil, it undergoes rapid nitrification process, more than half (up to 60%) of the nitrogen leaches out or vaporizes in the form of nitrogen gas, ammonia & nitrous oxide due to the presence of denitrifying bacteria in the soil and plants will not be able to recover it efficiently and effectively which leads to reduced or lower nitrogen use efficiency (NUE).

This NUE ranges between 30 to 50%. Thus, two third of Urea-Nitrogen escapes from soil and is not utilised by plants. Further, faster conversion of urea into nitrate which results in accumulation of nitrates in soil / underground water, if it is not utilised or uptake by plant body. This accumulation of nitrate in underground water is very difficult to remove and causes diseases such as blue baby syndrome.

This implies that there is a need to regulate the urea hydrolysis and nitrification. This is done by some chemical / natural agents are called as Nitrification inhibitors. However, most of the nitrification inhibitors are costly chemicals beyond reach of Indian farmers. Coating Urea with Neem oil or Neem cake has been proved to be an effective natural alternative to these chemicals. It has been scientifically established that Neem oil serves as an effective inhibitor if coated on Urea and increases the soil fertility by maximum utilization of nitrogen which results in increased crop growth and yield.

Benefits

1. Using neem-coated urea improves soil health, boosts agriculture yields (*paddy by 5.79%; sugarcane by 17.5%; maize by 7.14%; soybean by 7.14%; and red gram by 16.88%*) and checks its diversion to non-agro activities.
2. Neem coating leads to more gradual or slow release of urea-N, helps to higher uptake of nutrients which results in higher yields.
3. The neem-coated variety is applied in smaller amount since the plants stay greener for longer period.
4. Lower underground water contamination due to reduced leaching of urea.
5. Neem serves as a natural insecticide collection of neem seeds is needed for manufacturing of neem coated urea. This would generate employments in rural areas and opportunity for entrepreneurs to commercialize local Neem.

6. Neem-coating will help to check heavily subsidized urea's proliferage to chemical industry and other uses such as making of adulterated milk.
7. Neem-coated urea significantly cuts down costs for plant protection, besides reducing pest diseases.
8. Use of urea came down from 152 kg per hectare crop into 149 kg and crop yield jumped from 2,028 kg per hectare to 2,042 kg.
9. Saving of 10% of the losses of urea would amount to 2 million tons of urea or a reduction in subsidy component to the tune of 1,700 crores per annum (considering total subsidy on urea to be 18,000 crores per annum).
10. Proportional saving in the consumption of naphtha or natural gas.
11. Reduction in environmental pollution of ground water due to reduced leaching of nitrates and gaseous emissions.
12. Resources and Development of Small Scale Industries in rural areas.

Study Conducted by the Bengaluru-based Agricultural Development and Rural Transformation Centre at the Institute for Social and Economic Change observed that apart from the increase in yield, Neem Coated Urea application has other useful effect in paddy and wheat crops.

- At Uttar Pradesh, farmers have observed that the menace of Neel Gai has reduced significantly in paddy crop.
- At Panipat, farmers observed no incidence of leaf folder and stem borer in paddy crop.
- At Sangrur and Gurdaspur, in the states of Punjab, farmers observed that the incidence of white ant was reduced with the use of Neem coated Urea in wheat crop.

This is because of fragrance of Neem oil that on dissolution was released in the standing water and insecticidal properties of Neem.

Government Policy on Neem Coated Urea

Government has aimed at checking the excessive use of urea which is deteriorating the soil health and adversely impacting overall crop yield. According to officials in both Agriculture and Fertiliser Ministries, the soil health is deteriorating because of excessive use of urea and it has disturbed the ideal N (nitrogen) P (phosphorus) and K (potash) ratio of 4:2:1.

Fertiliser Secretary J K Mohapatra has said that neem coated urea also works as insecticide and it will cost just 5 per cent more than the cost of normal urea which is

about Rs. 260 per tonne and about Rs. 10 per bag. Fertiliser Minister Ananth Kumar had said that with the use of neem coated urea, there will be more yield to the extent of 15-20 per cent and with less use of urea to the extent of 15-20 per cent.

In January 2015, the government allowed the urea producers to produce up to 100% of production as Neem coated urea. Further, the government made it mandatory to produce at least 75% of domestic Urea as Neem coated. The current policy is that Government has mandated all indigenous producers of Urea to produce 100% of urea as Neem coated urea only.

Government asked farmers to use 'neem-coated' urea as it helps in increasing the yield with its minimum use. By reducing the use of urea, country can save foreign exchange as India has to import about 70-80 lakh tonnes of the fertiliser to meet its annual demand and likely to save Rs. 6,500 crore subsidy outgo.

Industry body Fertiliser Association of India has welcomed the move and said that the industry has been demanding for removing the cap on production of neem coated urea for last many years and added, it will help for maintaining the ideal nutrient ration in soil.

National Fertilizers Limited (NFL) became the first company in India that was granted the permission to produce and market the Neem Coated Urea, vide Govt of India. Today the company has facilities at all its 3 Units namely Nangal, Bathinda, Panipat and Vijaipur for production of Neem Coated Urea. Neem coated urea produced at these production facilities is marketed in all the 14 States where the company is marketing its Urea.

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SEAWEED IN AGRICULTURE: ENHANCING SOIL HEALTH AND CROP PRODUCTIVITY

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Introduction

Seaweed is a broad term used to describe multicellular macroalgae, encompassing green algae (*Chlorophyta*), brown algae (*Phaeophyceae*), and red algae (*Rhodophyta*) (Mouritsen *et al*., 2017). While the term generally refers to macroalgae, it is occasionally applied to microalgae and certain marine plants. Most seaweeds are benthic, meaning they attach to the seafloor using a structure called a *holdfast*. They typically possess a *stipe* (a stem-like feature) and *blade*-like structures that resemble leaves (USDC NOAA, 2021). A notable exception is *Sargassum*, a free-floating brown algae species that does not attach to the ocean floor (Simons *et al*., 1906). The distribution of seaweed types is closely related to light availability at different depths. Green seaweeds are found in shallow waters, brown seaweeds in mid-depths, and red seaweeds inhabit deeper areas, often reaching depths of up to 30 meters (Mouritsen *et al*., 2017). Seaweed species vary greatly in size from tiny forms only a few millimeters in length to massive species that can grow up to 50 meters (Mouritsen *et al*., 2017).

Worldwide, approximately 1,800 species each of green and brown seaweeds and around 6,200 species of red seaweeds have been identified. Brown seaweeds are often collectively

known as *kelp*, but they are also referred to by common names like *rockweed* and *wracks* (Pereira *et al*., 2019). Of the three types, red seaweeds are the most diverse. Along with green seaweeds, they are more closely related to terrestrial plants, whereas brown seaweeds are evolutionarily more distant from land flora (Mouritsen *et al*., 2017).

Seaweeds grow abundantly in shallow marine ecosystems and are cultivated in both open-sea farms and land-based aquaculture facilities (McHugh and Dennis, 2003). Wild brown seaweeds are commonly harvested from genera such as *Laminaria*, *Undaria*, and *Hizikia*, while cultivated species used in agriculture and environmental monitoring include *Ascophyllum*, *Ecklonia*, *Fucus*, and *Sargassum* (Begum *et al*., 2018). Green seaweeds like *Ulva* and *Enteromorpha* are widely employed as bioindicators due to their ability to accumulate heavy metals (Kim *et al*., 2017). Red seaweeds, particularly those from the genus *Porphyra*, are commonly used in food and are a staple in many Asian cuisines (Mouritsen *et al*., 2017). Seaweed coloration is closely linked to depth and light availability: green seaweeds dominate shallow waters, brown seaweeds are found at intermediate depths, and red seaweeds often inhabit deeper zones, extending to depths of up to 30 meters (Mouritsen *et al*., 2017). Their size ranges widely—from tiny species just a few millimeters tall to large forms that can grow up to 50 meters in length (Mouritsen *et al*., 2017).

Table: 1 Mineral compositions of seaweeds (Deepak *et al*., 2019)

Mineral compounds (ug/g of extract)	Red algae (*Lithothamnion calcareum*)	Green algae (*Ulva lactuca*)	Brown algae (*Stoechospermum marginatum*)
Copper	4.89	0.38	8.64
Manganese	57.50	62.00	8.75
Zinc	15.80	1.01	19.92
Iron	915.00	0.37	858.50
Potassium	5.17	113.00	29.65
Magnesium	25.80	18.30	9.60
Cobalt	0.08	0.06	3.47
Chromium	0.82	nd	16.60
Lead	0.15	nd	0.40
Nickel	1.84	10.40	25.20
Cadmium	0.07	2.00	5.90
Sodium	4.15	185.00	39.11
Calcium	351.50	195.26	2053.40
			
	Lithothamnion calcareum	*Ulva lactuca*	*Stoechospermum marginatum*



Fig 1: Different types of Seaweed

Fertilization

Seaweed serves as an effective organic biofertilizer due to its rich composition of macro- and micronutrients, humic acids, and naturally occurring phytohormones, all of which contribute to enhanced soil fertility and plant growth (Raghunandan *et al*., 2019). Additionally, seaweed-derived fertilizers contain beneficial compounds such as polysaccharides, proteins, and fatty acids, which improve the soil's moisture and nutrient retention capacity. Notably, seaweed contains a broader spectrum of trace minerals compared to fertilizers derived from animal byproducts.

The use of seaweed fertilizers has also been linked to increased crop tolerance to abiotic stressors such as drought, salinity, and low temperatures factors that typically reduce yield and crop quality. Studies have shown that wheat plants treated with seaweed extracts accumulate higher levels of osmoprotectants like proline, amino acids, and total proteins, which help mitigate stress effects (Ali *et al*., 2021). Furthermore, foliar application of seaweed extract has been reported to enhance the uptake of essential nutrients including nitrogen, phosphorus, potassium, and sulfur in soybean crops (*Glycine max*) (Rathore *et al*., 2009).

Soil conditioning

As a soil conditioner, seaweed-based fertilizers significantly enhance the physical properties of soil, particularly its aeration and water-holding capacity (Raghunandan *et al*., 2019). This is especially beneficial for clay soils, which often suffer from poor porosity and low organic matter content. Compounds such as humic acid and soluble alginates present in seaweed

help bind with metallic radicals in the soil, promoting the aggregation of clay particles. This aggregation improves soil texture, enhances aeration, and increases moisture retention by encouraging the disaggregation of compact clay structures (Zodape, 2001). Furthermore, the breakdown of alginates contributes organic matter to the soil, thereby boosting its fertility (Raghunandan *et al*., 2019). Brown seaweeds, particularly *Sargassum* species, are especially noted for their soil-conditioning benefits. These seaweeds contain not only soluble alginates but also alginic acid, which stimulates microbial activity in the soil. Alginic acid facilitates the bacterial decomposition of organic matter, thereby enhancing the populations of nitrogen-fixing bacteria. The metabolic byproducts of these bacteria further enrich the soil with natural conditioners, promoting long-term soil health and productivity (Zodape, 2001).

Bio-remediation of polluted soils

Seaweed serves as an effective bio-remediator by adsorbing harmful pollutants from the environment. This biosorption process is driven by various functional groups present on the algal surface such as ester, hydroxyl, carbonyl, amino, sulfhydryl, and phosphate groups, which enable the binding of heavy metal ions (Raghunandan *et al*., 2019). Species like *Gracilaria corticata var. cartecala* and *Grateloupia lithophila* have demonstrated the ability to remove a wide range of heavy metals, including chromium (III and VI), mercury (II), lead (II), and cadmium (II). Additionally, *Ulva* spp. and *Gelidium* spp. have been shown to enhance the degradation of persistent organic pollutants like DDT in contaminated soils, potentially reducing its bioavailability (Kantachote *et al*., 2004). Despite its promise, further research is needed to fully understand and optimize seaweed's role in soil remediation within agricultural systems. One critical concern is the potential transfer of accumulated heavy metals from seaweed-based fertilizers to food crops, which could pose risks to public health (Kantachote *et al*., 2004).

Another promising application of seaweed in sustainable agriculture is its conversion into biochar, a carbon-rich product that improves soil fertility and structure. Seaweed-derived biochar enhances soil organic matter and nutrient content (Roberts *et al*., 2015). Notably, different seaweed types yield biochars with distinct chemical properties; for example, red seaweeds produce biochar rich in potassium and sulfur and tend to be more acidic compared to biochar derived from brown seaweeds (Roberts *et al*., 2015). Although still an emerging field, early findings suggest that selective breeding and optimization of seaweed species may enable the production of custom biochars tailored to specific soil types and crop requirements

Integrated pest management

The incorporation of seaweed into soil has been shown to enhance crop health and increase resistance to various diseases (Raghunandan *et al*., 2019). Seaweeds are rich in diverse bioactive compounds such as steroids, terpenes, acetogenins, and amino acid-derived polymers, which contribute to their ability to combat plant pathogens and pests (Raghunandan *et al*., 2019). The application of seaweed extracts has been reported to reduce the incidence of harmful pests, including nematodes and insect species (Machado *et al*., 2019). Although seaweed alone can mitigate the adverse effects of nematode infestations, its combined use with carbofuran a chemical nematicide has demonstrated even greater effectiveness (Sultana et al., 2019). Moreover, certain seaweed species, such as *Sargassum swartzii*, *Padina pavonica*, and *Caulerpa denticulata*, have been observed to inhibit the early growth and development of a variety of insect pests (Machado *et al*., 2019).

Conclusion

The use of seaweed in agriculture offers a sustainable and environmentally friendly approach to improving crop productivity and soil health. Seaweed-based products, including extracts and biofertilizers are rich in essential nutrients, growth-promoting hormones, and bioactive compounds that enhance seed germination, plant growth, yield, and resistance to abiotic and biotic stresses. Additionally, their application supports soil microbial activity and structure, contributing to long-term soil fertility. As the demand for eco-conscious farming practices increases, integrating seaweed into agricultural systems presents a promising solution for achieving higher productivity with minimal environmental impact. Continued research and innovation in seaweed cultivation and processing will further strengthen its role in future sustainable agriculture.

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SOIL TOMOGRAPHY: PRINCIPLES, APPLICATIONS, AND ADVANCEMENTS

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Introduction

Soil tomography is an advanced geophysical technique used for subsurface imaging, allowing researchers and engineers to analyze the internal structure of the soil. This method is widely applied in geological, environmental, and engineering fields to assess soil composition, detect anomalies, and support construction and agricultural activities. By using waves, electromagnetic signals, or other forms of energy propagation, soil tomography enables non-invasive, high-resolution subsurface exploration.

Principles of Soil Tomography

Soil tomography is based on the principle of transmitting energy waves through the ground and analyzing their interactions with different soil layers. The time it takes for these waves to travel through the soil, their attenuation, and the variations in their velocity provide crucial information about the subsurface structure. The technique relies on the concept of refraction and reflection of waves, which differ based on soil density, moisture content, and composition. By collecting data from multiple angles and depths, sophisticated algorithms reconstruct a detailed image of the underground profile.

Techniques and Methods Used in Soil Tomography

Several techniques are employed in soil tomography, each suited for different applications and subsurface conditions:

Seismic Tomography:

This method utilizes seismic waves generated by artificial or natural sources. By

measuring wave travel times and velocities, it provides a detailed image of the subsurface. Seismic tomography is particularly effective for identifying rock formations, fractures, and voids within the soil.

Electrical Resistivity Tomography (ERT):

In this technique, electrical currents are introduced into the ground, and the resulting voltage differences are measured. Different soil materials exhibit varying resistivity levels, allowing researchers to distinguish between sand, clay, water-saturated zones, and other formations.

Electromagnetic Tomography:

This method uses electromagnetic waves to probe the subsurface, detecting changes in conductivity and permittivity. It is particularly useful for identifying buried objects, groundwater flow paths, and contaminant plumes.

Ground Penetrating Radar (GPR):

GPR employs high-frequency radio waves to scan the ground and create an image of subsurface features. It is commonly used in archaeological surveys, utility detection, and shallow soil investigations.

Acoustic Tomography:

This technique uses sound waves to analyze subsurface properties. It is particularly useful in marine and wetland environments, where water content influences the soil's acoustic properties.

X-ray Computed Tomography (CT): Used in soil structure analysis, enabling precise imaging of soil aggregates, cracks, and water movement.

Magnetic Resonance Imaging (MRI): Ideal for studying plant root systems, water uptake, and nutrient absorption in soil without disturbance.

Optical Coherence Tomography (OCT): Applied in plant structure imaging and disease detection in crops.

Applications of Soil Tomography

Soil tomography has a broad range of applications across different industries and scientific fields:

Geotechnical Engineering: Used in site investigations before construction to assess soil stability, detect voids, and evaluate ground conditions for infrastructure projects such as

bridges, tunnels, and buildings.

Environmental Studies: Essential in detecting underground contaminants, monitoring groundwater movement, and assessing soil pollution levels.

Archaeology: Aids in locating buried artifacts, ancient structures, and historical remains without disturbing the site.

Mining and Mineral Exploration: Assists in locating mineral deposits and understanding rock formations beneath the surface.

Landslide and Earthquake Studies: Provides crucial data on fault lines, subsurface stress, and potential landslide-prone areas, helping in disaster preparedness.

Tomography in Agriculture and Soil Science

Tomography is becoming an indispensable tool in agriculture and soil science, providing non-invasive methods to analyze soil structure, moisture content and distribution, and plant root systems and penetration, nutrient content, improving irrigation management and crop yield predictions. The ability to visualize subsurface features allows researchers to optimize crop growth, enhance irrigation planning, and assess soil health.

1. **X-ray CT in Soil Analysis**

X-ray computed tomography is widely used to study soil porosity, compaction, and root-soil interactions. It enables precise imaging of soil aggregates, cracks, and water movement, which are essential factors in assessing soil quality. Researchers use CT images to evaluate the impact of different agricultural practices on soil health, making it a valuable tool for sustainable farming.

2. **MRI in Root System Studies**

Magnetic Resonance Imaging (MRI) has been adapted to study plant root growth and function without disturbing the soil. It allows researchers to monitor water uptake, nutrient absorption, and root system development over time, providing critical insights for improving crop resilience and yield.

3. **Electrical Resistivity Tomography (ERT) for Soil Moisture Mapping**

ERT is an effective technique for measuring soil moisture variations, helping farmers optimize irrigation schedules and conserve water resources. This method is particularly useful in drought-prone regions where efficient water management is essential for sustainable agriculture.

4. **Seismic and Acoustic Tomography for Soil Stability**

These techniques help in detecting subsurface anomalies such as fractures, voids, and changes in soil density. They are particularly useful in preventing soil erosion, assessing land suitability for farming, and ensuring the stability of agricultural infrastructure.

5. **Optical Coherence Tomography (OCT) in Plant and Disease Studies**

OCT provides high-resolution images of plant tissue micro-structures, aiding in the early detection of diseases, pest damage, and plant stress. By analyzing vascular tissues, researchers can improve plant breeding programs and disease resistance.

Advantages of Soil Tomography

Soil tomography offers several benefits compared to traditional soil investigation methods:

Non-destructive Testing: Allows subsurface examination without excavation or drilling, preserving the site's integrity.

High Resolution and Accuracy: Produces detailed images of soil structures, enabling precise analysis and decision-making.

Rapid Data Collection: Provides real-time or near-real-time insights into subsurface conditions.

Versatility: Applicable across various environments, including drylands, wetlands, urban areas, and mountainous regions.

Cost-effective: Reduces the need for extensive physical sampling and laboratory testing, saving both time and money.

Limitations of Soil Tomography

Despite its advantages, soil tomography has some limitations:

Data Interpretation Complexity: Requires advanced processing techniques and expertise to interpret results accurately.

Equipment and Operational Costs: High-end tomography equipment can be expensive, and field operations require trained personnel.

Depth Limitations: Some tomography methods are less effective for deep subsurface investigations due to wave attenuation or signal loss.

Environmental Interference: External factors such as moisture content, soil heterogeneity, and underground utilities can affect measurement accuracy.

Challenges and Future Directions

While tomography offers numerous benefits, challenges remain in its widespread adoption in agriculture and soil science. The high cost of equipment, technical expertise required for data interpretation, and limitations in imaging depth pose significant barriers. Additionally, environmental factors such as soil heterogeneity and moisture variations can influence imaging accuracy.

Future advancements in artificial intelligence (AI) and machine learning are expected to enhance tomography by improving image reconstruction, automating analysis, and increasing accuracy. The development of portable and cost-effective tomography systems will make these technologies more accessible to farmers and researchers worldwide. Moreover, interdisciplinary research integrating tomography with robotics, nanotechnology, and precision agriculture is likely to revolutionize soil and crop management.

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Conclusion

Soil tomography has revolutionized imaging across multiple disciplines, including agriculture, geotechnical engineering, environmental monitoring, and archaeology. It provides a non-invasive and highly detailed means of analyzing soil structure, root dynamics, and moisture distribution. Despite challenges such as cost and complexity, continuous advancements in technology and interdisciplinary research are making tomography more accessible and effective.

In agriculture and soil science, it provides a non-invasive and highly detailed means of analyzing soil structure, root dynamics, and moisture distribution. Despite challenges such as cost and complexity, continuous advancements in technology and interdisciplinary research are making tomography more accessible and effective. By leveraging tomography, scientists and farmers can optimize resource use, improve crop yields, and enhance environmental sustainability. As innovations continue, tomography will remain an essential tool in addressing global agricultural challenges, ensuring food security, and promoting sustainable land management.

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SUCCESS STORY ON RAJASRI BIRDS REARING AS BACKYARD POULTRY FOR IMPROVING LIVELIHOOD OF FARMERS

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Introduction

Raising of local poultry breeds in backyard is an important source of livelihood for the rural people in Tirupati District of Andhra Pradesh. These birds are exclusively raised in the backyards, spread across all categories of households. However, the problems of low weight gain, less number of eggs per bird and high mortality of chicks with indigenous birds are some of the hindrances in backyard poultry to be evolved as a small scale enterprise, which need to be overcome through introduction of improved variety of birds with better performance levels.

2. **Activities implemented by KVK:**

"Rajasri" a dual purpose bird, developed for backyard farming has a great potential due to its versatile capacity to adapt in various climatic conditions. These birds are exclusively raised in the backyards with a capacity of 160-170 eggs/year. Dr.YSRHU-KVK, Nellore-2 (Periyavaram) popularized rearing of dual purpose Rajashri birds which are highly acclimatized as backyard poultry in Tirupati District of Andhra Pradesh by providing training on backyard poultry rearing and supplying 5weeks old chicks to SC farmers under SC Sub Plan for enhancement of their income and livelihood in rural areas.

3. **Output of the intervention**:

Performance of Rajasri birds in comparison with desi birds:

S.No.	Practice	Egg Production (Egg/Bird/Year)	COC (Rs.)	Gross Income (Rs./bird/Year)	Net Income (Rs./bird/Year)	B:C Ratio
1	**Rajasri**	156	670	2320	1650	3.46:1
2	**Desi birds**	54	780	1530	750	1.96:1






4. **Outcome and impact**:

It is evident that Rajasri bird performed better in terms of productivity and provided subsidiary income to the family. It was also noticed that there was significant increase in consumption of eggs and meat among beneficiary families. Besides the sale of eggs and meat, the farmers were also generating income by continuing the enterprise by reproducing the chicks by using automatic egg incubator which was installed at Dr.YSRHU-KVK, Periyavaram. After witnessing the performance of these Rajasri poultry birds, most of the farmers of Venkatagiri division showed interest in rearing of Rajasri birds as backyard poultry. At present, a total of 120 farmers other than SC farmers from several villages of Venkatagiri and Balayapalle mandals have adopted rearing of Rajasri poultry birds as backyard poultry.

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BANANA CULTIVATION IN KERALA: IMPLEMENTS AND INNOVATIONS FOR ENHANCED PRODUCTIVITY

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Introduction

Banana is a major fruit crop cultivated in Kerala, ranking third in terms of area under cultivation—following jackfruit and mango. It is one of the most consumed fruits in the state and plays a significant role during festivals and traditional events. In Thiruvananthapuram district alone, banana is grown across 3,507 hectares with a productivity rate of 9,134 kg/ha. However, banana cultivation comes with its share of challenges. From planting to harvest, farmers invest heavily in labor, inputs, pest control, and protection from environmental factors such as birds, animals, and heavy rains. These challenges often affect the successful harvesting of banana bunches.

To help farmers overcome these issues, small farm implements have been introduced and demonstrated by the **Krishi Vigyan Kendra (KVK)**. These technologies have shown promising results in improving efficiency, reducing losses, and enhancing the quality of the produce. Three of the most widely adopted tools in Kerala include:

1. KAU Banana Bunch Covering Device

Problem Addressed: Insect, bird, and pest damage to banana bunches, which lowers quality and market value.

Solution: The Banana Bunch Covering Device, developed in 2019 by Kelappaji College of Agricultural Engineering and Technology, Tavanur (KAU), allows for easy and efficient covering of banana bunches using non-woven fabric, particularly for red and Nendran varieties



Key Features:

- **Lightweight**: Weighs just 1 kg.
- **Farmer-friendly**: Easy to use and operate.
- **Components**: Includes a supporting pole, curved aluminum assembly, elastic spring, screws, rubber band, and a rope mechanism.
- **Reusable**: Covers can be used for up to three seasons with proper care.

Performance:

- **Traditional Method**: 10–15 minutes per plant using a ladder.
- **With Device**: Field capacity of 20–30 bunches per hour.
- **Benefit**: Reduces labor, increases speed, and is cost-effective. Can be shared among farmers or rented by groups.

2.ICAR-CIAE–NRCB Battery-Operated Banana Pseudostem Injector

Problem Addressed: Pseudostem weevil infestation, which causes up to 30–40% yield loss if untreated.



Limitations of Traditional Methods:

- Spraying leads to chemical loss due to evaporation.
- Labor-intensive and environmentally unsafe.
- Syringe-based stem injections are time-consuming and inefficient.

Solution: The Battery-Operated Pseudostem Injector, developed by ICAR-CIAE (Coimbatore) and ICAR-NRCB (Trichy), allows precise injection of insecticide directly into the banana pseudostem.

Key Components:	**Operation**:
Chemical tank (8–16 ℓ capacity)	Injects 5–10 ml of solution at 45 cm and 150 cm height.
Battery-operated pump	Angled insertion (45°) ensures optimal pest control.
Electronic controller and embedded system	Performed during the 5th to 8th month after planting.
Non-return valve	
Injection lance with calibrated needle	

- **Performance (Nendran Variety)**:

Parameter	**Result**
Quantity Injected	5–10 ml
Field Capacity	325 trees/hour
Spillage Efficiency	2%
Injector Efficiency	96%
Yield	147 q/ha

3. Banana Collar Ring and String Support System

Problem Addressed: Crop loss due to toppling from wind and the weight of mature banana bunches, particularly before harvest.

Solution: The **Collar Ring and String Support System** stabilizes banana plants to prevent lodging due to external forces.

Components:

- **Collar Ring**: Made from 4 mm GI wire.
- **UV-Stabilized Plastic Rope**: 5 mm thick.

- **Caurine Poles**: For end-row anchoring.
- **GI Stay Wire** and **Wooden Pegs**: Provide support and anchorage.



Setup Procedure:

1. Attach the collar ring to the top junction of the pseudostem where the fruit peduncle emerges.
2. Connect rings using UV-stabilized plastic ropes in a longitudinal fashion across the row.
3. Secure the ropes with slipknots for easy release.
4. Anchor the ropes at four ends using caurine poles and pegs for stability in both directions.

Benefits:

- Reduces crop losses due to plant toppling.
- Enhances yield stability.

  Provides secure support for each plant throughout the growing cycle

Conclusion

These innovative and farmer-friendly implements have proven to be effective in enhancing banana cultivation in Kerala. By adopting the KAU Bunch Covering Device, the Battery-Operated Pseudostem Injector, and the Collar Ring and Support System, farmers can significantly reduce losses, lower input costs, and improve yield quality and quantity. KVK's successful demonstrations have encouraged wide adoption, and these technologies are contributing positively to the sustainability and profitability of banana farming in the region.

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CLIMATE SMART AGRICULTURE: ADAPTING TO CHANGING ENVIRONMENTAL CONDITIONS

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Abstract

Climate Smart Agriculture (CSA) is a comprehensive approach designed to ensure sustainable food security under changing climate conditions by enhancing productivity, resilience, and reducing greenhouse gas emissions. With agriculture being the primary livelihood for nearly 50% of India's population and contributing significantly to GDP, the sector is highly vulnerable to climate change. Rising temperatures, erratic rainfall, and extreme weather events are adversely impacting crop yields, livestock health, and natural resources. CSA addresses these challenges through integrated strategies that include the use of climate-resilient crop varieties, efficient water management, precision farming, and diversified cropping systems. It also promotes sustainable livestock practices such as improved breeds, rotational grazing, and manure management. Key pillars of CSA—enhanced productivity, increased resilience, and reduced emissions—aim to transform agricultural systems in alignment with environmental, social, and economic goals. By adopting CSA, farmers can better manage climate risks and contribute to a more sustainable and secure food system.

Introduction

Climate Smart Agriculture (CSA) is an approach that enhances sustainable food production by increasing resilience and reducing emissions. It addresses economic, social, and environmental goals to combat climate change impacts on agriculture and food security.

Climate

Climate refers to the long-term patterns of temperature, humidity, wind, and precipitation in a particular region.(typically 30 years or more)

Key elements of climate include Average temperature, Seasonal changes, Rainfall patterns, Humidity levels and Wind behavior.

Climate change :

Climate change refers to a long-term shift in average weather patterns, encompassing changes in temperature, precipitation, and extreme weather events. These shifts can be caused by both natural and human activities.

Impacts on Agriculture and Food Production

Agriculture' is the main occupation for 50 % of population in India. Agriculture and allied sectors contribute 16% per cent of the Indian GDP.

Major adverse impacts of climate change on agriculture are owing to Increase in temperature, Change in rainfall pattern, Weather hazards, Decline in soil and water quality, Shifting dynamics of insects, diseases, soil flora and fauna, Intrusion of sea water on land, Biotic and Abiotic stresses arising due to climatic extremes.

Climate Smart Agriculture

Climate Smart Agriculture is nothing but the approach for developing agricultural strategies to secure sustainable food security under climate change. It is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate. It integrated the three dimensions of sustainable

development (Economical, Social and Environmental) by jointly addressing food security and climate challenges.

CSA = Sustainable Agriculture + Resilience – Emissions.

The three Pillars of CSA		
Increasing Farm Productivity and income	Enhanced resilience	Reduced Emissions
CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish, without having a	Reduce vulnerability to droughts, pests, diseases and other climate-related risks and shocks; and improve the capacity to adapt longer-	Reduce greenhouse gas emissions of the food system, avoid deforestation due to cropland expansion, and increase the carbon

negative impact on the environment.	term stresses like increased seasonal variability and more erratic weather patterns.	sequestration of plants and soils. Reduce global emissions by 5-7 giga tons of CO_2 equivalent by 2030.

Climate-smart key practices

- Crop management
- Livestock management
- Soil health management
- Agro-forestry
- Integrated food energy Systems
- Carbon Sequestration
- Improved Crop Varieties
- Climate Forecasting
- Precision Agriculture

Smart Crop Management

To build resilience in agriculture against climate change, several adaptive strategies can be employed. One key approach is the use of climate-resilient crop varieties, such as drought-tolerant, flood-tolerant, or heat-resistant seeds, which can better withstand extreme weather conditions. Another important strategy is adopting a diversified cropping system through intercropping and crop rotation, which helps reduce the risk of total crop failure — if one crop is affected by adverse conditions, others may still thrive. Additionally, efficient water management practices, including drip irrigation, rainwater harvesting, and the use of weather forecasts and soil moisture sensors to schedule irrigation, are essential for conserving water and ensuring crops receive adequate moisture. Lastly, timely planting and harvesting aligned with expected weather patterns can help optimize yields and minimize losses due to unpredictable climatic events.

Smart Livestock management

To enhance the resilience and sustainability of livestock systems, several key practices can be adopted. Improved animal breeds that are more tolerant to heat, drought, or diseases help ensure productivity even under harsh climatic conditions. Implementing better feeding systems

by using high-quality, locally available feeds and optimizing grazing can promote healthy animal growth while reducing methane emissions. Rotational grazing is another effective method, where animals are moved between pastures to prevent overgrazing, support land recovery, and encourage grass regrowth. Manure management plays a dual role by reducing greenhouse gas emissions and improving soil health—manure can be collected and converted into biogas or compost. Regular animal health monitoring using mobile applications, sensors, and veterinary services enables early detection and control of diseases, thus minimizing economic losses. Lastly, water-efficient systems are vital to ensure a steady supply of clean drinking water to animals, particularly during droughts, supporting both animal welfare and resource conservation.

Smart Dairy farmer

A smart dairy farmer can adopt several innovative practices to enhance the resilience and sustainability of livestock management. To enhance the resilience and sustainability of livestock systems, a range of integrated practices can be implemented. One of the most effective strategies is the use of improved animal breeds that are naturally more tolerant to heat, drought, and diseases, ensuring consistent productivity even under changing climatic conditions. Better feeding systems, involving high-quality and locally available feeds along with optimized grazing, contribute to improved animal health and reduced methane emissions. Rotational grazing—systematically moving livestock between pastures—not only prevents overgrazing but also allows vegetation to regenerate, maintaining soil fertility and pasture productivity. Effective manure management, such as converting waste into biogas or compost, can reduce methane emissions and enhance soil quality. Additionally, animal health monitoring through mobile apps, sensors, and regular veterinary services supports early disease detection and control, helping to prevent major losses. Finally, installing water-efficient systems ensures animals have access to clean drinking water, especially crucial during droughts, thereby promoting both animal well-being and efficient resource use.

Soil and water management

Sustainable soil and water management practices are essential for improving agricultural productivity and climate resilience. Conservation tillage, which involves minimal soil disturbance, helps maintain soil structure and reduce erosion. Advanced irrigation techniques like drip and sprinkler systems ensure efficient water use by delivering moisture directly to the root zones. Practices such as cover cropping, where protective plants are grown to shield the soil,

and mulching, which retains moisture and suppresses weeds, further enhance soil health. Rainwater harvesting and storage systems provide a reliable water source during dry periods, while organic soil amendments like compost and manure improve soil fertility and structure. Using soil moisture data to schedule irrigation ensures crops get just the right amount of water, avoiding waste. Agroforestry, the integration of trees with crops, offers benefits such as shade, improved biodiversity, and reduced soil erosion. Soil testing and precision fertilization help apply the right nutrients in the correct amounts, minimizing environmental impact. Additionally, treated wastewater can be reused safely for irrigation, and techniques like terracing and contour farming, especially on slopes, reduce runoff and prevent soil loss. Together, these practices form a comprehensive approach to sustainable land and water resource management.

Smart weather forecasting for water planning

On August 11, 2024, Prime Minister Narendra Modi launched 109 high-yielding, climate-resilient, and bio-fortified crop varieties developed by ICAR, covering 61 crops, including 34 field and 27 horticultural crops. Notable examples include Sahbhagi Dhan, a drought-tolerant rice variety that matures in 105 days, and AAA drought-tolerant maize, a collaborative initiative by Syngenta, CIMMYT, and partners to support small-scale farmers. Additionally, improved drought-tolerant pearl millet varieties such as *HHB 67 Improved* and *IPMH302* offer resilience under water-scarce conditions.

Actions Required for Implementation of Climate Smart Agriculture

To ensure food security in the face of climate change, it is essential to expand the evidence base and improve assessment tools that help identify effective agricultural growth strategies. These tools should pinpoint which practices, crops, technologies, and policies perform best under changing climate conditions. A robust policy framework and national consensus are also needed to support the large-scale implementation of such strategies, ensuring alignment between agricultural development and climate goals. Strengthening national and local institutions is crucial to enable farmers to manage climate risks and adopt context-specific methods, technologies, and systems. Additionally, improving access to financing—by linking agricultural and climate finance—can support widespread adoption of resilient practices and technologies, making agriculture more sustainable and climate-smart.

Assessment tools of Climate Smart Agriculture:

Sustainability Assessment of Food and Agriculture (SAFA) System:

Assessing sustainability in the agriculture and food sectors, including crop and livestock production, forestry and fisheries.

Ex-Ante Carbon Balance Tool (EX-ACT): This rating system was developed by FAO. it provides prior estimates of the impact on carbon balance.

Climate Risk Management (CRM): This integrated approach addresses vulnerabilities to short-term climate change and long-term climate change.

Resilience Index Measurement and Analysis (RIMA) - Socio-economic resilience, vulnerability assessment. Decision Support System for Agrotechnology Transfer (DSSAT) - Crop modeling, productivity under climate change.

Agricultural Stress Index System (ASIS) - Drought monitoring, risk reduction.

Government CSA Projects & Programs in India

National Innovations in Climate Resilient Agriculture (NICRA)

Launched by: Indian Council of Agricultural Research (ICAR) in 2011

Goal: Enhance resilience of Indian agriculture to climate change and variability

Key Components:

- Strategic research on climate-resilient crops and livestock
- Technology demonstrations in 151 Climate Smart Villages
- Capacity building for farmers and researchers

National Mission on Sustainable Agriculture (NMSA)

Under: National Action Plan on Climate Change (NAPCC)

Focus Areas: a program that aims to make agriculture more sustainable, productive, and climate resilient

- Water-use efficiency (like drip or sprinkler irrigation)
- Soil health management
- Conservation agriculture

National Agroforestry Policy (2014)

CSA Link: Encourages tree-based farming systems that sequester carbon, improve soil, and enhance drought resilience

Implemented by: Ministry of Agriculture and Farmers Welfare

NAFCC — National Adaptation Fund for Climate Change

Launched by: Government of India in 2015.

Objective: To provide financial support to projects that help communities adapt to the adverse effects of climate change, especially in sectors vulnerable to climate risks (like agriculture, water resources, forestry etc.).

Managed by: The National Bank for Agriculture and Rural Development (NABARD) acts as the National Implementing Entity (NIE)

Focus: It's specifically for adaptation (not mitigation), meaning helping people and ecosystems adjust to the changing climate rather than trying to reduce greenhouse gas emissions.

Budget – 350 crore for the year 2015-16 and 181 cr. For 2016-17

Global Roadmap to 2050 for Food and Agriculture

Zero-carbon agriculture focuses on reducing greenhouse gas emissions by enhancing production efficiency and increasing carbon sequestration. It promotes the use of digital agriculture tools like robotics and drones, encourages integrated crop-livestock systems, and supports affordable technologies for smallholders, making sustainable, low-emission farming accessible and effective across diverse agricultural landscapes.

Conclusion

Climate Smart Agriculture (CSA) presents a comprehensive and forward-thinking solution to the challenges posed by climate change in the agricultural sector. By integrating strategies that enhance resilience, improve productivity, and reduce greenhouse gas emissions, CSA promotes a balanced approach to sustainable agriculture. Ultimately, CSA serves as a critical pathway for achieving long-term agricultural sustainability while addressing the urgent challenges of climate change.

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NANO UREA: THE FUTURE OF SUSTAINABLE FERTILIZERS

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Introduction

Nano Urea represents a significant innovation in the field of agricultural fertilizers, aiming to address the inefficiencies and environmental challenges associated with conventional urea. Developed and commercialized by the Indian Farmers Fertiliser Cooperative Limited (IFFCO), Nano Urea Liquid is gaining traction as a potential game-changer for sustainable agriculture (Kiran and Samal, 2021). . Here's a review of Nano Urea, encompassing its concept, mechanism, advantages, disadvantages, and current research trends, drawing from the provided search results and general knowledge:

Nano Urea: A Promising Innovation for Sustainable Agriculture

Nano Urea is a nanotechnology-based nitrogen fertilizer, typically available in liquid form. Unlike conventional granular urea, which has particle sizes in millimeters, Nano Urea contains urea particles in the nanoscale range (typically 20-50 nanometers). This minute size is the key to its enhanced efficiency. IFFCO's Nano Urea Liquid, for instance, contains 4.0% total nitrogen (w/v) evenly dispersed in water. A 500 ml bottle of Nano Urea Liquid is claimed to be equivalent in nitrogen impact to one 45 kg bag of conventional granular urea (Kiran and Samal, 2021).

How Does Nano Urea Work?

The efficacy of Nano Urea stems from its unique physical properties:

- **Smaller Particle Size and High Surface Area:** The extremely small size (20-50 nm) of nano urea particles gives them a significantly higher surface area-to-volume ratio compared to conventional urea prills. This larger surface area allows for more contact points with plant tissues, facilitating better absorption.
- **Foliar Application:** Nano Urea is primarily applied as a foliar spray directly onto plant leaves. The nanoscale particles can easily penetrate plant cuticles and enter plant cells through openings like stomata and plasmodesmata (which are typically around 40 nm in diameter).
- **Efficient Absorption and Translocation:** Once inside the plant, the nano-nitrogen particles are efficiently absorbed and transported through the plant's vascular system (phloem cells) to where nitrogen is most needed for growth and development. Unutilized nitrogen can even be stored in plant vacuoles and slowly released, providing a sustained nutrient supply.
- **Reduced Losses:** Conventional urea suffers from significant losses due to volatilization (conversion to gaseous ammonia), leaching (washing away into groundwater), and runoff into water bodies. The targeted delivery and efficient absorption of Nano Urea significantly reduce these losses, leading to much higher Nutrient Use Efficiency (NUE), often cited as over 80% (Kumar *et al*., 2023).

Advantages of Nano Urea:

- **Higher Nutrient Use Efficiency (NUE):** This is the most significant advantage. Due to its direct foliar application and efficient absorption, a much higher proportion of the applied nitrogen is utilized by the plant, reducing wastage.
- **Increased Crop Yields:** Numerous studies and field trials (including those by IFFCO across 11,000 locations on over 90 crops) have reported increased crop productivity and yields (e.g., up to 8% or more) with the application of Nano Urea, sometimes even with a reduced rate of conventional urea (Dhivyalakshmi *et al*., 2025).
- **Economic Benefits for Farmers:** While the initial cost per bottle might seem comparable or slightly higher than a bag of urea, the reduced quantity required (one 500 ml bottle replaces one 45 kg bag) leads to significant cost savings in terms of fertilizer purchase, transportation, and storage. This translates to higher net returns for farmers (Lohar *et al*., 2023).

- **Environmental Friendliness:**
    - **Reduced Greenhouse Gas (GHG) Emissions:** By minimizing volatilization and denitrification, Nano Urea reduces the emission of nitrogen oxides (NOx) and nitrous oxide (N2O), potent greenhouse gases.
    - **Reduced Water Pollution:** Less leaching and runoff mean significantly reduced contamination of groundwater and surface water bodies with nitrates.
    - **Improved Soil Health:** Reduced application of bulk chemical fertilizers can contribute to better soil microbial activity and overall soil health.
    - **Lower Carbon Footprint:** The production process of Nano Urea is generally considered more energy-efficient and generates fewer pollutants compared to conventional urea manufacturing (Gaddi *et al*., 2024).
- **Ease of Handling, Storage, and Transportation:** The liquid form and small bottle size make Nano Urea much easier for farmers to transport, store, and apply compared to bulky 45 kg bags of conventional urea.
- **Better Food Quality:** Some studies suggest that crops grown with Nano Urea exhibit improved nutritional quality in terms of protein and nutrient content.
- **Complementary to Existing Practices:** Nano Urea can be easily integrated into existing farming practices and can be mixed with bio-stimulants, other water-soluble fertilizers, and many agrochemicals (after a jar test for compatibility) (Tiwari, 2023).

Disadvantages and Challenges:

- **Yield Equivalence Concerns:** While IFFCO reports positive results, some independent studies, like one from Punjab Agricultural University (PAU), have indicated a *decrease* in rice and wheat yields (21.6% for wheat, 13% for rice) and lower grain nitrogen content when Nano Urea was used as a complete replacement for conventional nitrogen fertilizers. These studies emphasize the need for more long-term, comprehensive field evaluations (5-7 years) to ascertain its full equivalence and sustainability (Kumar *et al*., 2024).
- **Cost Considerations (Per Unit N):** While the *overall* cost for farmers might decrease due to reduced quantity, some analysts suggest that the cost of Nano Urea *per unit of nitrogen* can be higher than conventional urea.

- **Application Method Dependence:** Nano Urea is designed for foliar application, requiring farmers to have sprayers, which might be an additional investment or effort for some. Proper spraying techniques are crucial for optimal absorption.
- **Long-Term Environmental Impact:** While touted as eco-friendly, long-term studies on the accumulation of nanoparticles in soil, their potential impact on soil microbiota, and their ultimate fate in the food chain are still areas that require more comprehensive research (Upadhyay *et al*., 2023).
- **Awareness and Adoption:** Despite promotional efforts by organizations like IFFCO and the Indian government (e.g., through PMKSKs, drones for application), widespread adoption by all farmers requires significant awareness campaigns, demonstrations, and consistent positive results.
- **Regulatory Framework:** As nanotechnology in agriculture is relatively new, evolving regulatory frameworks and safety guidelines are essential for the widespread and safe adoption of products like Nano Urea.

Research and Promotion in India (with a focus on IFFCO):

India has been at the forefront of Nano Urea development, primarily driven by IFFCO.

- **Development and Approval:** IFFCO Nano Urea (Liquid) is the world's first nano-fertilizer to be notified by the Fertilizer Control Order (FCO, 1985), Government of India, following extensive bio-efficacy and toxicology tests.
- **Manufacturing and Availability:** Several Nano Urea plants have been set up in India by IFFCO and other PSUs (like NFL, RCF) to meet the demand. It is made available through various channels, including Pradhan Mantri Kisan Samridhi Kendras (PMKSKs).
- **Promotion and Awareness:** The Government of India and fertilizer companies actively promote Nano Urea through various activities such as awareness camps, webinars, field demonstrations, Kisan Sammelans, and the "Namo Drone Didi" scheme, which provides drones to women Self Help Groups for efficient application of nano fertilizers.

Conclusion

Nano Urea represents a promising leap towards more sustainable and efficient nutrient management in agriculture. Its ability to significantly improve Nutrient Use Efficiency, reduce environmental pollution, and potentially offer economic benefits to farmers is compelling. However, ongoing, robust, and long-term independent research is crucial to fully understand its

long-term impacts on diverse crops, soil health, and the broader ecosystem. As research progresses and adoption increases, Nano Urea could play a pivotal role in ensuring food security while minimizing the environmental footprint of agriculture, aligning with global goals for sustainable development.

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PATHOGEN-ASSOCIATED MOLECULAR PATTERN IN PLANT PATHOGENIC ORGANISM (FUNGI, BACTERIA AND VIRUS)

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Introduction

Pathogen-associated molecular patterns (PAMPs) are small molecular motifs conserved within a class of microbes, but not present in the host. They are recognized by toll-like receptors (TLRs) and other pattern recognition receptors (PRRs) in both plants and animals. This allows the innate immune system to recognize pathogens and thus, protect the host from infection. This initiation of the immune response consists of the secretion of inflammatory cytokines and chemokines. PAMPs can initiate the maturation of immune cells, which can travel to the primary lymph node and trigger the adaptive immune system that involves the production of antibodies against specific antigens.

Although the term "PAMP" is relatively new, the concept that molecules derived from microbes must be detected by receptors from multicellular organisms has been held for many decades, and references to an "endotoxin receptor" are found in much of the older literature. The recognition of PAMPs by the PRRs triggers activation of several signaling cascades in the host immune cells like the stimulation of interferons (IFNs) or other cytokines.

The PAMP pathway, or Pathogen-Associated Molecular Pattern pathway, is a crucial part of the innate immune system in both plants and animals. It involves the recognition of molecular patterns (PAMPs) that are specific to pathogens, but not found in the host organism, by pattern recognition receptors (PRRs). This recognition triggers a cascade of signaling events, ultimately leading to the activation of immune responses.

Here's a more detailed breakdown:

1. Recognition:

- **PAMPs:**

These are conserved molecular structures found on pathogens, such as bacterial cell walls, viral RNA, or fungal components.

- **PRRs:**

These are receptors on host cells, like Toll-like receptors (TLRs) and other receptors, that specifically bind to PAMPs.

2. Signaling:

- **Activation of Signaling Cascades:** The binding of PAMPs to PRRs initiates intracellular signaling pathways.
- **MAPK Pathways:** These are common signaling pathways activated by PAMP recognition, leading to the activation of transcription factors.
- **Other Pathways:** Depending on the specific PAMP and PRR involved, other pathways like the NF-κB pathway can also be activated.

3. Immune Response:

- **Cytokine and Chemokine Production:**

The signaling pathways ultimately lead to the production and release of cytokines and chemokines, which are signaling molecules that recruit and activate other immune cells.

- **Inflammation:**

The release of inflammatory mediators contributes to the inflammatory response, which helps to clear the infection.

- **Adaptive Immunity:**

In some cases, PAMP signaling can also trigger the adaptive immune response by activating T and B cells, leading to the production of specific antibodies.

In Plants:

- **PTI (PAMP-triggered immunity):** In plants, PAMP-triggered immunity is the first line of defense against pathogens.
- **Restricting Pathogen Proliferation:** PTI helps to restrict the growth and spread of pathogens.

- **Effector-Triggered Immunity (ETI):** Plants can also activate a second layer of immunity called effector-triggered immunity, which is triggered by pathogen effectors that interfere with PTI signaling.

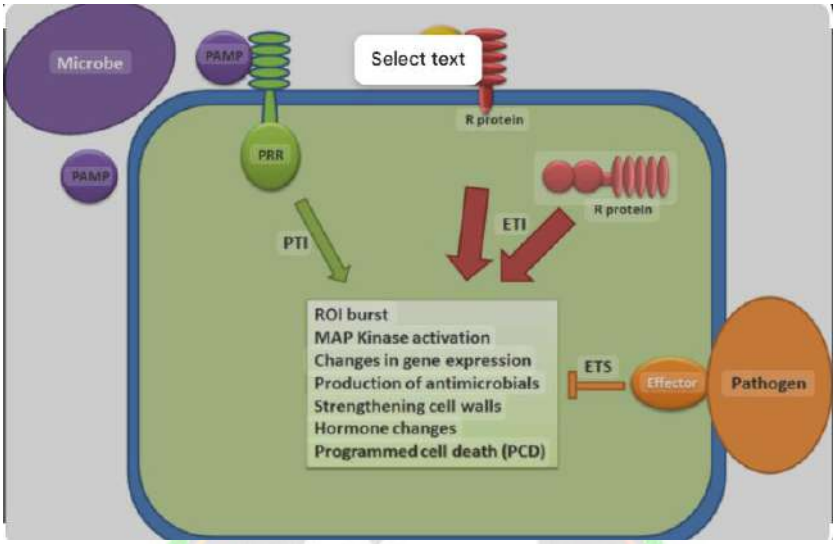


Fig.1. Pathogen-associated molecular patterns (PAMPs) in fungi

Role in the Immune System

Cells that promote innate immunity express PRRs. Not only do PPRs detect PAMPs, they also detect host-derived damage-associated molecular patterns or DAMPs that are products of tissue damage. Toll-like receptors (TLR), complement receptors (CR), and scavenger receptors are among the many types of PRRs that monitor the cellular environment for invaders and damage. The innate and adaptive immune systems are connected through TLRs because it leads to the secretion of cytokines and chemokines that go on to help recruit lymphocytes.

Innate Immunity

When an antigen breaches the protective barrier and enters the tissue , the initial response is known as the innate immune system. PAMPs are critical to the initiation of the innate immune system because they recognize the danger, which will result in a response against the threat. PAMPs interacting with PRRs initiate signaling pathways that produce chemokines and pro-inflammatory cytokines–creating an inflammatory environment.

The cytokines and chemokines secreted lead to the translocation of dendritic cells that activate T cells, which "help" B-cells secrete antigen-specific antibodies, which is associated with the adaptive immune response. None of these events can occur without the PRR–PAMPs interaction.

Types

A vast array of different types of molecules can serve as PAMPs, including glycans and glycoconjugates. Flagellin is also another PAMP that is recognized via the constant domain, D1 by TLR5. Despite being a protein, its N- and C-terminal ends are highly conserved, due to its necessity for function of flagella.Nucleic acid variants normally associated with viruses, such as double-stranded RNA (dsRNA), are recognized by TLR3 and unmethylated CpG motifs are recognized by TLR9. The CpG motifs must be internalized in order to be recognized by TLR9. Viral glycoproteins, as seen in the viral-envelope, as well as fungal PAMPS on the cell surface or fungi are recognized by TLR2 and TLR4.

Gram-negative bacteria

Bacterial lipopolysaccharides (LPSs), also known as endotoxins, are found on the cell membranes of gram-negative bacteria, are considered to be the prototypical class of PAMPs. The lipid portion of LPS, lipid A, contains a diglycolamine backbone with multiple acyl chains. This is the conserved structural motif that is recognized by TLR4, particularly the TLR4-MD2 complex. Microbes have two main strategies in which they try to avoid the immune system, either by masking lipid A or directing their LPS towards an immunomodulatory receptor.

Peptidoglycan (PG) is also found within the membrane walls of gram-negative bacteria and is recognized by TLR2, which is usually in a heterodimer of with TLR1 or TLR6.

Gram-positive bacteria

Lipoteichoic acid (LTA) from gram-positive bacteria, bacterial lipoproteins (sBLP), a phenol soluble factor from *Staphylococcus epidermidis*, and a component of yeast walls called zymosan, are all recognized by a heterodimer of TLR2 and TLR1 or TLR6.

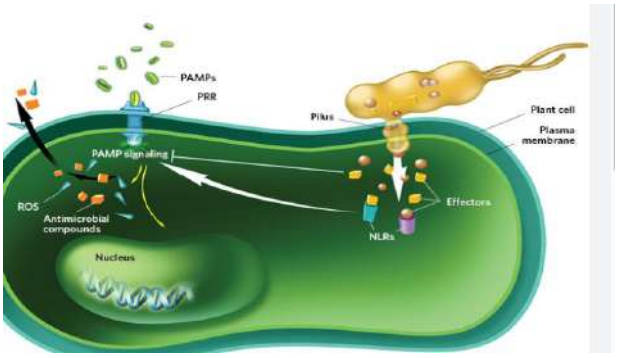


Fig.2. Pathogen-associated molecular patterns (PAMPs) in gram positive and negative bacteria

However, LTAs result in a weaker pro-inflammatory response compared to lipopeptides, as they are only recognized by TLR2 instead of the heterodimer.

Viruses

Viral DNA, viral RNA and CpG are the PAMPs associated with viruses. The PRRs that sense viruses are TLRs, RLRs (Rig-I-like receptors), CLRs (C-type lectine receptors), and inflammasomes/DNA sensors. CLRs are mainly located on myeloid cells, and RLRs are cytoplasmic, mainly detecting viral RNA. TLRs can be located on cell surfaces and the endosomal membrane. Bacterial infections can be intracellular and extracellular, while viral infections are largely intracellular, so endosomal TLRs are most associated with virus detection. TLR3 recognizes dsDNA while TLR7 and TLR8 detect ssRNA. TLR9's detection of hypomethylated CpG DNA could differentiate virus from self molecules because of the higher CpG content in viruses. PAMPs recognition by TLR is followed by signaling pathways. Viruses may evade the immune response by interacting with proteins in these signaling pathways. By attacking the proteins involved in these pathways, viruses can attempt to evade their destruction.

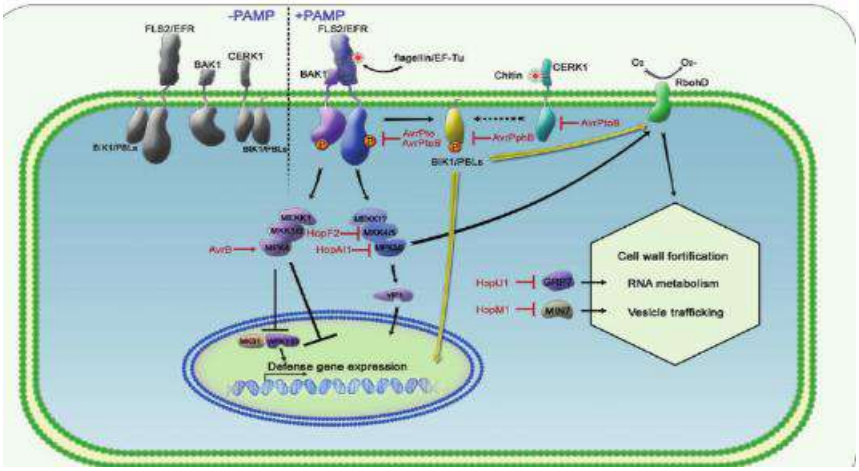


Fig.2. Pathogen-associated molecular patterns (PAMPs) in plant pathogenic virus

In mycobacteria

Mycobacteria are intracellular bacteria which survive in host macrophages. The mycobacterial wall is composed of lipids and polysaccharides and also contains high amounts of mycolic acid. Purified cell wall components of mycobacteria activate mainly TLR2 and also TLR4. Lipomannan and lipoarabinomannan are strong immunomodulatory lipoglycans. TLR2 with association of TLR1 can recognize cell wall lipoprotein antigens from *Mycobacterium tuberculosis*, which also induce production of cytokines by macrophages. TLR9 can be activated by mycobacterial DNA.

History

First introduced by Charles Janeway in 1989, PAMP was used to describe microbial components that would be considered foreign in a multicellular host. The term "PAMP" has been criticized on the grounds that most microbes, not only pathogens, express the molecules detected; the term microbe-associated molecular pattern (MAMP), has therefore been proposed. A virulence signal capable of binding to a pathogen receptor, in combination with a MAMP, has been proposed as one way to constitute a (pathogen-specific) PAMP. Plant immunology frequently treats the terms "PAMP" and "MAMP" interchangeably, considering their recognition to be the first step in plant immunity, PTI (PAMP-triggered immunity), a relatively weak immune response that occurs when the host plant does not also recognize pathogenic effectors that damage it or modulate its immune response.

Conclusion

The PAMP pathway is a fundamental mechanism by which the immune system detects and responds to pathogens. By recognizing molecular patterns on pathogens, the immune system can initiate a diverse range of responses to eliminate the threat

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FROM RESIDUE TO RICHNESS: PEANUT MILK RESIDUE CHOCO BALLS, A NUTRI-DENSE TREAT

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Abstract

Peanut milk residue, a by-product of peanut milk production, is often discarded as waste. However, this residue is rich in nutrients and bioactive compounds. This study aimed to develop a novel value-added product, peanut milk residue choco balls, and evaluate their nutritional properties. The results showed that the choco balls had high protein, fiber, and healthy fat content, as well as a rich antioxidant profile. The product also exhibited good texture and sensory properties. This study demonstrates the potential of peanut milk residue as a valuable ingredient for the development of nutri-dense food products.

Introduction

The peanut milk industry has experienced significant growth in recent years, driven by increasing demand for plant-based milk alternatives. However, the production of peanut milk generates a substantial amount of residue, which is often discarded as waste. This residue, rich in nutrients and bioactive compounds, presents an opportunity for value-added product development. Peanut milk residue is a good source of protein, fiber, and healthy fats, making it an attractive ingredient for food product development. Additionally, the residue contains antioxidants and other bioactive compounds, which can provide potential health benefits. The objective of this study was to develop a novel value-added product, peanut milk residue choco balls, and evaluate their nutritional properties.

Materials and Methods

Peanut milk residue was collected from a local peanut milk production facility. The residue was dried and ground into a fine powder. The powder was then mixed with cocoa powder, sugar, and coconut oil to form a dough. The dough was shaped into small balls and refrigerated for 30 minutes to set. The peanut milk residue choco balls were analyzed for their nutritional content using standard methods. The analysis included protein, fiber, healthy fats, and antioxidant content. The physicochemical properties of the choco balls were also evaluated, including texture, color, and sensory properties.

Results and Discussion

The results of the nutritional analysis are presented in Table 1.

Table 1: Nutritional Content of Peanut Milk Residue Choco Balls

s.no	Nutrient	Content (per 100 g)
1	Protein	15.2 g
2	fiber	8.5 g
3	Healthy Fats	20.1 g
4	Carbohydrates	56.2 g

The results show that the peanut milk residue choco balls have high protein, fiber, and healthy fat content.The peanut milk residue choco balls were evaluated for their texture, color, and sensory properties. The results are presented in Table 2.

s.no	Property	value
1	Texture	8.0
2	colour	7.5
3	Sensory score	8.5

Discussion

The results of this study demonstrate the potential of peanut milk residue as a valuable ingredient for the development of nutri-dense food products. The peanut milk residue choco balls had high protein, fiber, and healthy fat content, as well as a rich antioxidant profile. The product also exhibited good texture and sensory properties.

Conclusion

This study highlights the potential of peanut milk residue as a valuable ingredient for food product development. The peanut milk residue choco balls developed in this study offer a

nutri-dense and sustainable alternative to traditional chocolate products. Further research is needed to explore the scalability and commercial viability of this product.

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AN EMERGING ZOONOTIC DISEASE NIPHA VIRAL ENCEPHALITIS

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Abstract

Nipahvirus or Nipah viral encephalitis is an emerging zoonotic disease. It is endemic to south-east Asia and the western Pacific, with outbreaks occurring in Malaysia, Singapore, Philippines, India and Bangladesh. It can be transmitted by its primary reservoir of fruit bats, through intermediate animal hosts such as pigs and by human-to-human spread via contact with known Nipah virus patients**.** It is a negative - sense, non-segmented, single stranded RNA virus of the family of paramyxoviridae, genus Henipavirus and is closely related to hendra virus. The natural reservoir of the virus is represented by frugivorous bats (flying foxes) also called fruit bats belonging to the *Pteropu*s genus. Viral infection is mainly acquired by bats saliva, urine, faeces and birth fluids. Virus affected animals mostly having severe febrile encephalitis. First line of treatment is Ribavirin can reduce the mortality of acute Nipah encephalitis. Diagnosis may be done with polymerase chain reaction and serological test like Enzyme – linked immunosorbant assay. The only way to prevent infection in people is by raising awareness about the risk factors and preventive measures to protect themselves.

Keywords: Nipah virus, Nipah viral encephalitis, Pteropid bats, Ribavirin

Introduction

Nipah virus (NiV) infection is a viral disease caused by a virus belonging to the Henipavirus genus, in the Paramyxoviridae family, responsible for a zoonosis whose main clinical manifestations in humans are respiratory and neurological. Nipah virus infection is an

emerging bat-borne zoonotic disease transmitted to humans through infected animals (such as bats and pigs) or food contaminated with saliva, urine, and excreta of infected animals. It can also be transmitted directly from person to person through close contact with an infected person (although this represents a less common transmission route).

Nipah virus was first appeared in pigs at Malaysia and Singapore and humans are affected in Malaysia, Singapore, India and Bangladesh. The natural reservoir of Nipah virus are Fruit bats (Suborder- Megachiroptera) and insectivorous bats (suborder – Microchiroptera) in peninsular Malaysia is responsible for Nipah viral infection. In Malaysia there are 13 species of fruit bats (including 2 flying fox) and >60 species of insectivorous bats are present due to its high diversity of bats fauna (Johara *et al*., 2001). Intermediate host of the Nipah virus is pigs. The first outbreak of Nipah virus appeared in Malaysian pig farm which contain high level of fruit tress which attracted by bats and leave their saliva, urine, faeces and birth fluids. Nipah virus infection is also affected in dogs, cats, horses and goats.

The first human case of Nipah virus reported in Sungai Nipah in Malaysia in 1999. That's why the virus name noticed as Nipah virus. In 1999, pigs as well as human beings of some part of the Malaysia are affected by Nipah virus had the symptoms of acute encephalitis (Chua *et al*., 2000). In India first case of Nipha virus encephalitis reported in the Siliguri district of West Bengal state, bordering Bangladesh, in 2001. Neurological symptoms was observed during this outbreak. A second outbreak was reported in 2007 in Nadia district of West Bengal. In this second outbreak symptoms were observed in fever with acute respiratory distress and/or neurological symptoms. These two outbreak in India virus transmits from Bangladesh to west Bengal (Chadha *et al*., 2006).

Third outbreak was reported in Kozhikode and Mallapuram district of Kerala in 2018. This is the first nipha virus outbreak in South India. After that fourth outbreak in Ernakulam district of Kerala in 2109 and fifth in Kozhikode Kerala in 2021. Sixth in 2023, Kozhikode district of Kerala reported fourth time deadly bat-borne Nipah virus outbreak in five years. Bats from the Pteropus spp. or fruit bats were the probable source of the outbreak in Kerala state. Nipha virus transmits from fruit bats and causes a lethal, brain-swelling fever in humans.

Transmission

Transmission of Nipah viral infection from infected secretions of bats to the pigs. The virus is believed to have jumped from fruit bats of the Pteropus species to domestic pigs

paddocked under the trees where such bats roost. These contaminated fruits taken for humans and animals leads to infection of Nipah virus infected pigs can transmit disease by direct contact of their respiratory secretions to other animals. Peoples are affected by Nipah virus due to eating of fruits or raw date palm juice which is affected by saliva or urine of fruit bats. Contamination of drinking water infected with faeces, urine, parturition fluids. Virus can transmit from one person to another through respiratory droplets (Gurley *et al*., 2007).

Signs and Symptoms

Humans

Nipah virus infection can be asymptomatic to nonspecific influenza like symptoms can appear. Some common signs of fever, headaches, sore throat, confusion, disorientation, vomiting and muscle pain (myalgia), and segmental myoclonus are occur. Nipah virus can affect the CNS leads to severe vasculitis of small blood vessels result in endothelial damage, Hypertension, tachycardia and rapid deterioration with irreversible hypotension which leads to death. In severe cases, respiratory infection leads to dyspnoea (Wong *et al*., 2002). In advance cases, fatal encephalitis (inflammation of brain tissue), drowsiness, dizziness, altered consciousness and neurological signs are appearing finally coma within 24 – 48 hours.

Animals

In piglets mortality observed in 40%. Nipah virus mostly affects the respiratory as well as the nervous systems. It is also called as porcine respiratory and encephalic syndrome (PRES) and Barking pig syndrome (BPS). Common symptoms of muscle tremor with limb weakness and laboured breathing can occur. CNS infection leads to head pressing, twitching, trembling, muscle fasciculation, nystagmus, tetanic spasms, seizures and respiratory infection leads to nasal discharge, open mouth breathing, convulsion and death can occur (Hooper *et al*., 2001). In dogs distemper like symptoms are noticed with pyrexia, dyspnoea and purulent oculo – nasal discharge.

Diagnosis

Incubation period in pigs is approximately 4 to 14 days, human beings at 4 to 20 days and some cases reported in 45 days. The current infection can be diagnosed by high or four fold rises in specific IgM or IgG antibody (Ab) was detected in serum sample by Enzyme – linked immunoassays (ELISA) and modified ELISA developed based on relative reactivity of sera with Niv antigen. Tissue samples from necropsy – showed micro-infraction in CNS. Blood and

cerebrospinal fluid samples taken at before death of affected animals to culture the virus. The vero cells inoculation with cerebro spinal fluid (CSF) samples taken from the fatal cases of encephalitis causing a syncytial formation. The RT- PCR – in that RNA was extracted from human brain tissue (Fatal cases only). Two sets of primers were used for RT-PCR reaction (Chadha *et al*., 2006).

Differential Diagnosis

In earlier time the pigs which are affected by the Nipah virus had respiratory illness and it was ascribed as Japanese encephalitis (JE). JE is a mosquito born disease which is mostly endemic in a particular area where the pigs are mostly present. Pigs are the amplifying host of the JE (Chua *et al*., 2000). Symptoms which appear in the humans were distinct or deferred from JE. Nipah virus is differ from the JE by mostly affected the adult rather than children, members of the same households are mostly affected so, the viral infection had higher attack rate. But in JE, symptomatic encephalitis can occur in only 1 in 300 affected peoples but in Nipah virus affected peoples all had encephalitis. The Nipah virus outbreak is related to hendra virus but it had a clear-cut difference from hendra virus. Hendra virus transmitted from horse and all affected animals had respiratory infection with severe menigo - encephalitis (Osullivan *et al*., 1997).But in all Nipah virus animals do not had pulmonary involvement (Hooper *et al*., 2001).

Prevention and Control

- Transmission of Nipah virus can be effectively controlled by strict hygienic measures such as avoid consumption of partially bat eaten fruits and undercooked meat of infected animals.
- Avoid direct close physical contact of affected peoples
- Wear proper mask which contain NH-95 grade while attending patients with symptoms
- Proper sanitation of hands at regular interval
- Avoid visitors to enter the farm
- Proper cleaning of contaminated areas with using of 4% sodium hypochlorite.
- Proper isolation and quarantine period for the farm.
- Mass eradication of the infected animal in the farm and after culling proper burial site are selected and disinfected with chlorinated lime.

- Educative campaigns should be created to make public aware of this viral zoonotic diseases.
- Most important biosecurity measures to avoid the likelihood of the bats reservoir coming into contact with pigs.

Treatment

There is no known treatment or vaccine available for either human or animals. Intensive supportive care with treatment of symptoms is the main approach to managing the infection in people. There is no proven treatment recommended for Nipah virus disease. Some observational data suggests that Ribavirin may be of use in reducing mortality among patients with encephalitis caused by Nipah virus disease. There is no data/evidence of its usefulness as a prophylactic drug (Chong *et al*., 2001).There are research project going on by using Monoclonal antibodies as treatment for Nipah Virus disease. Systemic treatment only now currently available, there is no proper vaccination and drug available for treating the virus. First line of treatment is Ribavirin can reduce the mortality of acute Nipah encephalitis (Chong *et al*., 2001).

Conclusion

NiV is an emerging infectious disease of public health significance for the countries in the Southeast Asia region, which is a natural habitat for the fruit bats. As NiV can be transmitted by various methods, there is a potential public health threat globally. Because NiV is an issue to be addressed by multiple stakeholders to promote health to all citizens, the concept of global health diplomacy holds a great promise to address the needs of global health security through its binding or nonbinding instruments enforced by the global governance institutions (e.g., the WHO's IHR).[52] The ministries of health and stakeholders (e.g. CEPI, CIDRAP) need to work together to develop a vaccine and ensure health security from this bat-borne disease. There is a great need to strengthen intersectoral coordination, review the treatment procedures, infection control practices, and ensure use of PPE and availability of drugs to handle the suspected cases in a better way.

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PLASMIDS AND THEIR SIGNIFICANCE

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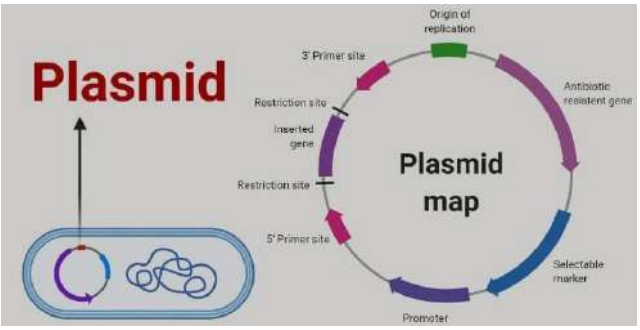
Abstract

Bacterial plasmids possess a wide range of regulatory mechanisms that control thefunctions nece ssary for their survival within a host and in the bacterial population. Recent studies at molecular and structural levels have enhanced our understanding of howbacteria control and transfer plasmids, revealing how complex and well-organized these control systems

Keywords: Plasmid, episomes, conjugation,virulence, competence, relaxase.

Introduction

A plasmid is a small extra-chromosomal, circular, double-stranded DNA molecule which is different from a cell's chromosomal DNA. They are mainly used as bacterial cloning vectors. Plasmids naturally exist in bacterial cells and are also found in some eukaryotic cells.The plasmid gene is able to provide several genetic advantages such as antibiotic resistance and is said to be semi-autonomous genetic elements as they replicate in steps with the host cell chromosome. Plasmids can be seen in a supercoiled or twisted shape before alkaline lysis and it can be checked using electrophoresis..



Before, it seems like a straight line, an open ring or as a twisted loop. Plasmids can be small or large and size varies from few thousands to 100,000 DNA bp. Plasmids attach themselves to the main DNA of the bacterial cells, which are called episomes. .In Proteus mirabilis, there are large plasmids which can break into different parts. Here, the genes can help the bacteria to fight against antibiotics

Importance and Role of Plasmids

Plasmids play a very important role in microbial adaptation and survival as they have the ability to transfer the genes, which are beneficial between bacterial species, via horizontal gene transfer.It helps the bacteria share of specific traits like antibiotic resistance, heavy metal tolerance, and breakdown of harmful chemicals, etc.In polluted sites or natural water bodies, these bacterial plasmids can be used to manage stress from all harmful substances.

Different kinds of plasmids

In 1985, Lewine categorized plasmids into several types based on their characters and functions

Different types of plasmids

Type of Plasmid	Description
Cryptic plasmids	They have no recognized functions but may help exclude incompatible plasmids.
Integrative plasmids	They can integrate into the host chromosome and replicate along with it; when integrated, they are also known as episomes.
Metabolic plasmids	They are involved in carrying genes related to metabolism.
Virulence plasmids	They encode toxins or other virulence factors and contribute to the pathogenicity of the host bacteria.
Conjugative plasmids	They carry tra-genes required for the conjugation process, enabling their transfer between bacterial cells.
Suicide plasmids / Z-plasmids	They can be delivered into a new host but cannot replicate in it.
Resistance plasmids (R-plasmids)	They carry multiple antibiotic resistance genes and help bacteria spread drug resistance.
Colicin plasmids	They are small plasmids that produce colicins, which are proteins capable of killing other bacteria

Modes of Plasmid Transfer

Conjugation

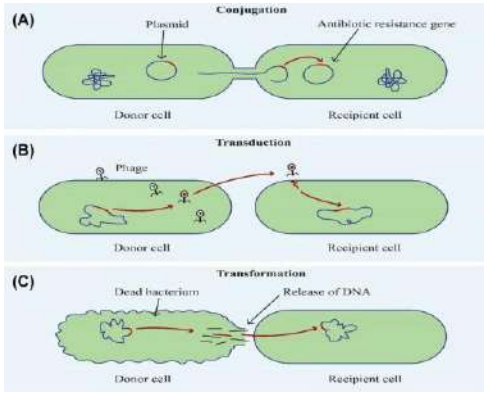
Conjugation is one of the major mechanisms of plasmid transfer in bacteria. In this process, direct physical contact is required between a donor and a recipient bacterial cell. The donor cell carries a conjugative plasmid and a pilus, which extends outward to establish contact with the recipient cell. The transfer of plasmid DNA during conjugation occurs in two steps. Initially, the plasmid DNA binds to an enzyme called **relaxase**, which facilitates its movement into the recipient cell. This movement starts passively. In the next step, the DNA is actively transported into the recipient through the **Type IV Secretion System (T4SS)**, which functions like a molecular channel.

Transduction

Transduction is another way of bacterial gene exchange involving **bacteriophages**\(viruses that infect bacteria).In this method, DNA is packagedintoa phageparticl e and then transferred into a new bacterial cell. There are mainly two types of transduction: **gene ralized** and **specialized** transduction. In **generalized transduction**, bacteriophages take up any fragment of DNA during the replication process and transfer it to another bacterium, thereby allowing any gene from the donor to be potentially passed on.In **specialized transduction**, the bacteriophage is integrated into a specific site in the bacterial genome and carries along nearby genes, which are then delivered to the new host during infection.

Transformation

Transformation is one of the natural methods of gene transfer, where a bacterium absorbs free DNA from its surrounding environment, which may be released by other lysed cells.



Mode of Transfer

In this process, the recipient bacterium must be in a physiologically prepared state called the competent state, where it is able to bind to, take in, and integrate the external DNA. Artificial transformations are also widely biology, where cells are treated electrically or chemically in order to become competent and take up plasmids during the process of cloning and genetic- -engineering.

Applications of Plasmids

Plasmids are circular DNA molecules that are widely used in the fields of science and biotechnology, as they have the ability to carry, replicate, and express genes in different organisms.

In genetic engineering, They have great importance in the production of proteins such as insulin, large-scale synthesis of antibiotics, and other biomolecules.

In gene therapy, plasmids are used to deliver correct copies of genes by replacing faulty genes in human cells to treat genetic diseases.

In the agricultural sector, plasmids can be used to modify animals and plants by transferring traits such as disease resistance and improved growth.

Plasmids are also a part of the bioremediation process through activities like degradation of pollu tants, toxin resistance, and survival in harsh conditions.

The modified microbes carrying plasmids can survive in natural environments and interact with native microbial communities.

Thus, it can be understood that plasmids are powerful tools with immense impact in various sectors such as medicine, agriculture, industry, environmental science, and fundamental genetic research.

Conclusion

Plasmids are powerful genetic elements, acting as nature's tools for adaptation, survival, and the sharing of genes among bacteria. Their unique ability to carry useful genes plays a vital role across various scientific and industrial sectors. As research continues, our understanding of plasmids grows deeper, paving the way to solve more complex problems in science and medicine. Ultimately, this knowledge enables us to harness plasmids to improve life through advancements in biotechnology and healthcare.

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Review Regulatory circuits for plasmid survival author links open overlay panel

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IMAGE-BASED CROP MONITORING IN PROTECTED HORTICULTURE: A GROWING TREND

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Introduction

Feeding a projected 9.3 billion people by 2050 poses a major challenge, with food demand expected to rise by 62% and hunger risk by 30% (UN, 2022). Crops like fruits and vegetables dominate food supply but require extensive land-4.82 billion hectares (37.18% of global land) were used for agriculture by 2021 (FAOSTAT, 2023). Traditional farming depends on manual labor, basic mechanization, and is vulnerable to climate change impacts like extreme weather and shifting rainfall. To meet future needs sustainably, we must boost food production without expanding farmland, while reducing water use and agrochemical inputs (Godfray *et al*., 2010; Searchinger *et al*., 2019).

In recent years, advanced technologies like image data acquisition and camera systems have become key tools in high-throughput phenotyping (HTP), particularly in controlled environments or small-scale fields. HTP research aims to develop climate-resilient, high-yield crop varieties. However, scaling crop monitoring to commercial protected environments brings both crop-specific and infrastructure-related challenges (Tian *et al*., 2022). In this article, we will explore how image-based monitoring works, the tools and sensors involved, its applications in horticultural crops, and the current challenges and future prospects in this evolving field.

How It Works

1. **Image Acquisition**: Periodic or continuous captures via fixed units or mobile platforms
2. **Pre-processing**:

   Normalize lighting differences (using reference objects or pixel-ratio corrections)

3. **Feature Extraction**:

   Plant height via depth analysis: color and texture analysis; thermal anomalies.

   Apply machine learning methodologies—CNNs, SVMs, YOLO—for disease detection, counting fruits, growth assessment.

4. **Alerts & Insights**:

   Compare growth curves (learned vs. optimal) to highlight issues 3–4 days before visual detection; generate nutrient stress, pest, and yield forecasts.

Methods & Imaging Technologies

Protected environments rely on three main platforms:

a. Stationary systems

- **Bench-top or gantry rigs**: Cameras scan small or potted plants (e.g., Arabidopsis, lettuce) from above or above sides.
- **Conveyor lines**: Plants are transported through imaging booths—ideal for research setups relying on automation .

b. Mobile platforms

- **Robot-mounted or trolley-mounted cameras**: These traverse between dense, tall greenhouse rows—especially useful for vertical or trellised crops like capsicum.
- **Fixed smartphone or Raspberry Pi sensors**: Positioned at crop canopy height to continuously photograph and relay data.

c. Aerial imaging (limited use inside)

Drones or overhead rigs are more common in fields but adapted in high-clearance greenhouses for canopy-level monitoring.

Tools & Sensor Types

Plant phenotyping uses different types of sensors that work across the electromagnetic spectrum, from ultraviolet to thermal ranges. Each sensor type is used to detect specific plant traits, though some traits can be measured by more than one sensor with different levels of accuracy.

Sensor Type	Monitored Traits
RGB Camera	Plant height, color, architecture, canopy coverage
RGB-D / 3D	Height, volume, leaf area via depth sensing

Sensor Type	Monitored Traits
Thermal IR	Leaf temperature, water stress detection
Fluorescence	Photosynthetic efficiency, early stress indicators
Hyperspectral	Biochemical profiling, disease, nutrient deficiency detection
Tomographic (MRI, PET, X-ray)	Root structure and internal physiology in research rare in commercial greenhouses



Fig 1: A sensor box deployed in a greenhouse, capturing environmental and imaging data for precision crop management.

Uses of Image-Based Monitoring in Horticultural Crops

Image-based monitoring offers a wide range of applications in horticultural crop management. One of its key benefits is the **early detection of pests and diseases**. By identifying symptoms such as leaf spots, wilting, mildew, fruit rot, or insect damage before they become visible to the naked eye, growers can take preventive action. For instance, powdery mildew in cucumber or leaf curl in chili can be detected in advance using this technology.

Another important use is in monitoring plant growth and development. Parameters such as plant height, leaf area, canopy density, and the number of fruits or flowers can be tracked over time. This helps in identifying different growth stages and making timely decisions, like pruning or nutrient scheduling.



Fig 2: A camera and sensor setup within a greenhouse collecting real-time plant data.

Water stress and irrigation management is another area where image-based tools are valuable. Thermal imaging can detect temperature changes in leaves or soil, indicating water stress. This enables precise irrigation scheduling, helping to avoid both under- and over-watering.

In terms of nutrition, **nutrient deficiencies** can be identified using multispectral or hyperspectral imaging. For example, nitrogen deficiency may cause yellowing of leaves, while magnesium or iron deficiency often leads to interveinal chlorosis. Early detection allows for timely and targeted fertilizer application.

For **yield prediction**, image data combined with AI models can estimate the number of fruits or vegetables per plant and forecast the expected yield per area. This supports better planning in marketing and supply chains.



Fig 3: A Kinect-style RGB-D camera system used for 3D plant monitoring in greenhouses.



Fig 4: A densified crop monitoring camera mounted in a greenhouse.

Uniformity and quality control is another benefit, as image-based systems can assess whether plants are growing evenly across rows or sections. They help identify weak or lagging plants that may require special attention

Uniformity and quality control is another benefit, as image-based systems can assess whether plants are growing evenly across rows or sections. They help identify weak or lagging plants that may require special attention.

Fruit ripeness and harvest readiness can also be assessed by monitoring changes in fruit color and size. This aids in determining the optimal harvest time for crops such as tomato, capsicum, strawberry, and grapes.

Lastly, these systems assist in **plant spacing and canopy management** by evaluating overcrowding or pruning needs. This ensures better light penetration and airflow, especially important in protected cultivation environments.

Suitable Crops & Real-world Examples

- **Capsicum (bell pepper)**: Mobile stereo-camera systems in glasshouses track plant height and leaf development.
- **Lettuce & Tomato**: Smartphone-based imaging detected suboptimal growth earlier than human visual inspection.
- **Sweet Pepper**: Advanced efforts include autonomous harvesting robots using machine vision for fruit localization .
- **Cucumber, Potatoes, Apple**: RGB/thermal/hyperspectral imaging used for disease and yield assessment.

Challenges & Research Needs

- **Light variability**: Complexity inside greenhouses with mixed natural/artificial lighting impacts image consistency.
- **Occlusion & scale**: Dense, vertical canopies and overlapping leaves complicate imaging.
- **Depth & 3D reconstruction**: RGB-D sensors may produce noisy data requiring smoothing .
- **Data scarcity**: Limited open datasets in protected environments slow AI development
- **Scalable systems**: Need affordable, robust sensor networks suitable for commercial operations

Future Directions

Advancements in image-based monitoring are enhancing crop management through innovations like YOLO (You Only Look Once)-based machine learning for real-time detection and sensor fusion of RGB, thermal, and spectral data for detailed analysis. Low-cost tools such as smartphones and Raspberry Pi are making these technologies more accessible. Hyperspectral imaging and tomography now enable precise stress detection and internal trait tracking, while digital twins offer virtual plant models for simulation and targeted interventions.

Conclusion

Image-based crop monitoring in protected horticulture is transforming greenhouse farming through affordable sensors, AI, and robotics. By using cameras and computer vision, it

offers a non-destructive, real-time method to assess plant health, detect problems early, and optimize inputs—enhancing yield, quality, and sustainability. Despite challenges like lighting and data gaps, this tech-driven approach marks a shift toward precision horticulture.

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IMPORTANCE OF TRUSS MORPHOMETRIC IN FISH TAXONOMY

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Abstract

Truss morphometry, a landmark-based geometric morphometric technique, has emerged as a robust tool in fish taxonomy and stock identification, effectively capturing shape variations across species with high precision. This study utilized a combination of image processing software (TPS series and PAST) to digitize and analyse morphometric landmarks on fish and crustacean specimens, enabling comprehensive shape quantification through a truss network of linear distances. Principal Component Analysis (PCA) and Discriminant Function Analysis (DFA) were employed to distinguish among morphologically similar species and assess population-level variations. The findings affirm that truss morphometry offers significant advantages over traditional methods, providing detailed, size-independent morphological differentiation crucial for effective fisheries management and conservation planning.

Keywords: Truss morphometry, Morphometrics, Stock identification and Fish taxonomy

Introduction

Truss analysis was created as a taxonomic method for separating morphologically similar species and also serve as a stock identification tool (Cardin and Friedland, 1999). Digital imaging technology and developments in analytical methods have changed the study of morphometric variation and boosted the power of morphometric analysis for stock identification (Bookstein, 1986). The morphometric study has substantially improved image processing techniques, making it a potent tool that can be used in conjunction with other stock identification

methods. Image processing is quick and inexpensive after the initial development of imaging systems and capabilities (Jayasankar *et al.,* 2004).

The Truss network system or Truss morphometry is a landmark-based approach of geometric morphometrics that captures information about the shape of an organism and has no restrictions on the directions of variation and localisation of shape changes (Cavalcanti *et al*., 1999). Truss is a technique of angular measurements, which is predicated on the measurement across the body by connecting a series of polygons from a following series of distances. The Truss network system is a uniform network that covers the entire crab or fish, and it should potentially increase the possibility of extracting variations across specimens (Strauss, 1985).

Morphometric character measurements with truss network analysis were performed using a combination of two software, TPSUtil and TPSDig2 software series (Rohlf and Marcus, 1993) and Paleontological statistics (PAST) which is used to derive morphometric data from each image (Hammer *et al.,* 2001). In PAST, which is used for multivariate analysis and paleontological modelling, the encrypted tps format image file description data is used as an input source (Bhosale *et al.,* 2018). Data normality features were used to translate all morphometric truss measurement findings. The allometric technique from the modified formula of Ihssen *et al.* (1981) and Hurlbut and Clay (1998) is used to modify data by eliminating all things that affect size.

Importance of TRUSS Morphometry

The empirical integration of geometry and biology is known as morphometrics. Its approaches must explicitly account for two completely different types of data: geographic location and biological homology. The goal of morphometrics is to investigate the relationships, causes, and effects between phenotypic features. Morphometric analysis is the study of landmarks, which is the analysis of data obtained from discrete morphometric points, as well as geometric relationships between them. Because of the substantial diversity associated with age, routine morphometric features have limitations in their use for stock identification. However, using the truss approach to examine landmarks can help avoid age reliance and aid in unbiased stock identification.

Truss measures are a powerful tool for analysing shape, and they're designed to cover the entire body, or at least the majority of it. In comparison to the classic morphometrics method, the truss network is a more useful and effective strategy for form descriptions; it has superior data

collecting and a wider range of analytical tools. As a result, it can distinguish between phenotypic stocks because the created landmarks cover the complete fish body with no loss of information.

Methods for comparing biological shapes and forms range from classic verbal and pictorial representations (Thompson, 1915) methods involving the tracing of outlines (Zelditch *et al.,* 1995), listing of measured linear distances among pairs of distinguishable landmarks on an organism (Robinson *et al*., 1993), and newer methods involving the geometric locations of landmarks (Walker & Bell, 2000). To quantify shape nowadays, multivariate analysis of numerous linear metrics (‘trusses’) throughout the body form is used. TRUSS Morphometry (Strauss & Bookstein, 1982) is a landmark analysis technique that examines data obtained from discrete morphometric points. Truss network systems constructed with the help of landmark points are powerful tools for stock identification of fish species. A sufficient degree of isolation may result in notable morphological, meristic, and shape differentiation among stocks of a species which may be recognizable as a basis for identifying the stocks. The characteristics may be more applicable for studying short – term, environmentally induced disparities, and the findings can be effectively used for improved fisheries management.

Methodology

Digitization of samples

The specimens collected were brought freshly to laboratory for furnishing Truss morphometric measurements. Specimens were first cleansed in running water, drained and placed on a flat base with vertical and horizontal grids having an area of one centimetre square (cm2), such as, a graph sheet in the background which was used in calibrating the coordinates of digital images. Then labelling was made with a specific code for identification for each individual specimen. The pereiopods and the abdominal flaps (Crustaceans) and dorsal fin, anal fin and pelvic fin are stretched on the graph sheet and pinned (finfish) and were placed on the platform in such a way that make their origin points visible. Digitization was done with digital camera and the images from the dorsal aspect of the cephalothorax of the species were obtained for further analysis.

Selection of Landmarks

The anatomical points that represent the similar developmental trait in all specimens are called landmarks and should be simple to locate. The network should resemble the shape of the

specimen from which it is derived. For this investigation, 12 landmark points were selected on the dorsal surface of cephalothorax which interconnected to form total 25 Truss measurements as shown in Fig. 1 for crab and Fig. 2 for fish.



Fig. 1. TRUSS Morphometry of Portunid crab

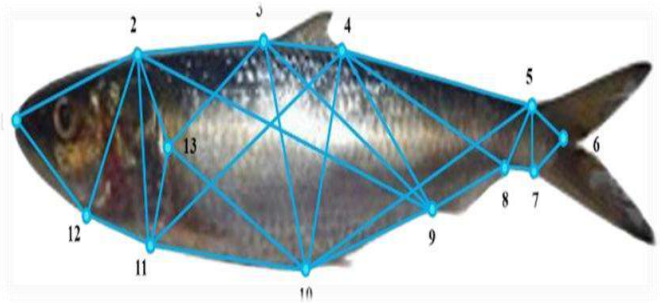


Fig. 2. TRUSS Morphometry of fish

Measurement of Truss distances

The morphometric data were extracted from the image of each individual specimen using a combination of software namely tpsUtil V1.46, tpsDig2 V2.16 and Paleontological statistics (PAST). A utility program called tpsUtil was primarily used to convert all photos from JPEG (*.jpeg) to TPS (*.tps), which is then utilised as input in tpsDig. A window-based application called tpsDig was used to digitise landmarks and outlines in specimen images for the analysis of geometric morphometry. The multivariate analysis software package, the PAST (Hammer *et al.*, 2001) designed specifically for statistical, graphing and modelling functions in palaeontological studies was used to extract morphometric data. The data encrypted TPS format image files were used as input source in PAST. The respective locations of landmarks to cover overall body form on the cephalothorax of crab using tpsDig V2.16. Twelve morphometric distances representing the dorsal aspect were selected based on their capacity to capture overall body shape in the studied portunid crabs. Then, the morphometric data were extracted using PAST.

Statistical analyses of truss characters

Descriptive statistics were obtained for all morphometric traits recorded. All the variations in size and shape between four species were analysed by PCA and DFA. The software applications of STATISTICA and PAST V.2.03 were used to conduct statistical analyses.

Principal Component Analysis (PCA)

PCA is an effective technique for morphometric data reduction (Mir *et al.*, 2013) and independent variable extraction (Samaee *et al*., 2009). It determines hypothetical variables or components accounting for the highest possible variance in a multivariate data (Davis, 1986; Harper, 1999). The new variables obtained are linear combinations of the original variables. It is a way of 25 identifying patterns in data from a number of variables and expressing the data in such a way as to highlight their similarities and differences. It finds the eigenvalues and eigenvectors of the variance-covariance matrix or the correlation matrix. The eigenvalues give a measure of the variance accounted by the corresponding eigenvectors (components). The percentages of variance accounted for by the corresponding eigenvectors are also expressed. The average within each group is subtracted before eigen analysis, thus eliminating the differences across groups, assuming groupings are given by a group column in the PCA. The 'Scree plot' is a simple plot showing the eigenvalues indicated the number of significant components. After this curve starts to flatten out, the components may be regarded as significant.

Discriminant Function Analysis (DFA)

The DFA is a statistical analysis to predict a categorical dependent variable, known as grouping variable, by one or multiple dependent variables by one or more independent categorical variables thus, effectively predicting the category membership in order to determine the ones that discriminate between groups. It gives insight into the group membership and the variables used to predict group membership. The DFA calculates the Percentage of Correctly Classified (PCC) fish. The Wilks' λ was used to compare the difference between all groups. A cross-validation using PCC estimate the expected actual error rates of the classification functions.

Conclusion

The long-term isolation of populations and interbreeding can lead to morphometric variations within populations, and this morphometric variation can provide a basis for population differentiation. The concept of stock separates the population into groups with different growth rates and reproductive dynamics, irrespective of genetic similarities. Morphometric differences among stocks of a species are recognized as important tool for evaluating the population structure and identifying stocks (Turan, 1999). The use of geometric pattern for determining the shape of an organism can be used as a tool for stock identification. It has evolved as effective

technique in stock management and conservation programmes in determining the stock. The Truss morphometric analysis is an effective identification tool to differentiate and delineate species for effective fisheries management and conservation.

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CROWDFUNDING – AN ALTERNATIVE SOURCE OF FINANCE FOR FARMERS

Article ID: AG-V05-I07-120

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Abstract

Agriculture remains a cornerstone of rural livelihoods in India, where a significant portion of the population depends on farming. However, smallholder and marginal farmers frequently struggle to obtain timely and affordable credit due to limitations within conventional financial systems. Crowdfunding has emerged as a novel and inclusive financing method that enables farmers to collect funds from numerous individuals through online platforms. This approach offers several advantages, such as non-debt-based capital, broader market visibility, and enhanced community participation. It supports sustainable agricultural practices, encourages crop diversification and enhances resilience to climate-related challenges, ultimately contributing to food security. The success of Crowdfunding relies heavily on farmers' ability to effectively communicate their stories, promote their campaigns and utilize digital tools - skills that are not universally accessible. With ongoing advancements in technology, supportive government policies, and increased public awareness, Crowdfunding has the potential to significantly reshape agricultural financing and foster rural development.

Introduction

Agriculture continues to play a critical role in sustaining rural communities, especially in India, where over half of rural households depend on it for their livelihoods. Small and marginal farmers often encounter obstacles in accessing affordable credit. Conventional financial institutions such as banks and cooperatives frequently require collateral, follow complex

procedures and view agriculture as a high-risk sector, making formal credit inaccessible to many farmers. This has driven the need for alternative financing mechanisms.

Crowdfunding

Crowdfunding refers to the process of raising small amounts of capital from a large number of individuals, typically through internet-based platforms. This financing model bypasses traditional intermediaries and creates a direct link between farmers and contributors, who may provide support either as donations or in exchange for future benefits. It has gained popularity as a democratized form of fundraising for various initiatives, including agricultural development.

The Role of Crowdfunding in Agriculture

- **Direct Consumer Engagement:** Crowdfunding allows farmers to connect with individuals who are interested in supporting agricultural projects that align with their values, such as sustainability and organic farming.
- **Promotion and Outreach:** Through digital platforms, farmers can share their journey, market their products and build relationships with potential supporters. This connection is increasingly valuable in today's environmentally-conscious marketplace.
- **Financial Independence:** As farmers face uncertainties like climate variability, fluctuating markets and restricted capital access, Crowdfunding provides an alternative that empowers them to take control of their financial needs.

Advantages of Crowdfunding

- **Access to Non-Debt Capital:** One of the most notable benefits of Crowdfunding is that it allows farmers to secure funding without taking loans or relinquishing ownership. This is especially important for small-scale farmers operating on thin margins.
- **Marketing and Pre-Sales Opportunities:** In addition to raising funds, Crowdfunding also serves as a promotional tool. Campaigns can attract early customers and supporters, enabling farmers to establish a loyal customer base even before production begins.
- **Increased Visibility and Trust:** Engaging directly with backers promotes transparency and accountability - qualities that are highly valued by modern consumers. Successful campaigns often receive media attention, further expanding outreach.

Challenges in Crowdfunding For Farmers

- **Limited Digital Skills:** Many farmers may lack the knowledge required to develop

effective Crowdfunding campaigns, including storytelling, video creation, and online marketing.

- **High Competition for Attention:** With numerous campaigns running simultaneously across platforms, it can be difficult to stand out. Communicating a unique value proposition becomes essential to attract and retain donor interest.
- **Donor Fatigue:** Potential backers may become overwhelmed by the volume of fundraising appeals. Therefore, authenticity and clarity in communicating the project's goals are crucial to maintaining engagement.

Crowdfunding: Role in Sustainable Agriculture and Food Security

Crowdfunding facilitates the adoption of environmentally friendly farming practices by providing financial support for eco-conscious projects such as regenerative agriculture, organic cultivation, and water conservation. These efforts help protect biodiversity and minimize environmental degradation. Crowdfunding allows farmers to diversify their crops, invest in innovative technologies, and strengthen resilience against climate impacts.

Empowering Local Farming Communities

By enabling community-driven support, Crowdfunding fosters a sense of collective responsibility and ownership. Contributors often become long-term advocates for the farms they support, promoting them within their social networks. These campaigns can have an educational aspect, helping raise public awareness about local food systems and sustainable agricultural practices. An informed community is more likely to support local producers and make conscious consumption choices.

Popular Crowdfunding Platforms in India

- **Rang De:** Offers peer-to-peer lending solutions aimed at rural entrepreneurs and farmers at affordable interest rates.
- **Ketto and Milaap:** Widely used donation-based platforms that allow farmers to raise money for medical emergencies, farming equipment, or infrastructure. Milaap also offers zero-interest loans.
- **Fuel A Dream:** Promotes sustainability and organic farming by supporting agriculture-focused projects through reward-based Crowdfunding.
- **Impact Guru:** Supports fundraising for rural development, healthcare, and education in farming communities.

- **Crowdera:** A fee-free platform designed to help farmer cooperatives and NGOs organize campaigns for rural empowerment.

Future Outlook

As digital infrastructure improves and consumers become more aware of the importance of sustainable food systems, Crowdfunding is poised to play a greater role in agricultural finance. Government involvement and public-private partnerships could further enhance the impact of this model by integrating it with formal support mechanisms like subsidies, grants, and training programs. In the long run, Crowdfunding can evolve into a reliable financing tool that supports innovation, inclusion, and resilience in the agricultural sector.

Conclusion

For small and marginal farmers, Crowdfunding presents a viable alternative to traditional credit systems. It provides access to essential resources while avoiding the burdens of debt and bureaucracy. Through digital platforms and community engagement, farmers can raise capital for critical investments in inputs, technology, and sustainable practices. However, challenges such as digital literacy, platform credibility, and regulatory clarity must be addressed to ensure widespread adoption. With appropriate institutional support and awareness-building, Crowdfunding has the potential to revolutionize rural finance and strengthen agricultural livelihoods.

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IMPACT OF DIGITAL TECHNOLOGY IN SUSTAINABLE ENTREPRENEURSHIP

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Abstract

Digital technologies are converting the entrepreneurial scenario and enabling the self-governing part of entrepreneurship. The rigorous advancements of digital technologies have transformed business surroundings and created an extensive range of prospects that have led to innovative ways to pursue entrepreneurship. The impact of digital technologies on entrepreneurship, entrepreneurship as a field of practice, and enterprise establishment has lent a helping hand in strategic growth of work environment and agency. To boost the reliability of management techniques and to guarantee that the business operates flawlessly along with maintaining a standard management mode in the functioning of an enterprise, there is a need be put into practice a form of management process for smooth running of an enterprise. The implementation of digital information technology is necessary for achieving effective company management. Digitizing of an enterprise is essential to increase the efficiency and sustainable functioning through dramatic changes in the quality of management, thereby increasing technological and decision making at all levels of management. Digital information technology classically reflects an organization's level of expansion, which influences both the administration and management of the organization. Advanced technological potentials enable businesses enterprise function to comprehend market conditions more speedily, take hold to the initial chance and maintaining stable business functions. The present paper therefore focuses on impact of digital technologies on sustainable entrepreneurship development.

Keywords: Digital Technology, Sustainable Entrepreneurship, SDGs, Internet, IoT

Introduction

Entrepreneurship is critical in facilitating economic growth and improving the quality of life. Entrepreneurship is associated with creating multiple opportunities, such as producing goods and services, infrastructural development, innovation, and creating jobs. However, recent years have seen an increase in the perception of entrepreneurship as a major cause of environmental and social problems, thus being a huge contributor to the lack of sustainability in society (Rosário et al., 2022). Digital technology has significantly transformed entrepreneurship by enhancing business operations, improving market reach, and fostering innovation. Various studies have explored the role of digital infrastructure, government policies, digital literacy, and emerging technologies like AI, IoT, and blockchain in entrepreneurial success. These digital tools streamline operations, enhance productivity, and contribute to environmental sustainability. Moreover, they open up new avenues for financial inclusion and service delivery.

Importance of Entrepreneurship

India's speedy population growth strengthens the unemployment problem. With a population exceeding 1.4 billion, the job market is under massive difficulty. The low level of human capital can be endorsed to several factors like high growth rate of population, poverty, unemployment inequality, illiteracy mortality and morbidity, low level of income and low level of consumption etc. These factors mostly prevail in developing countries like India and they are responsible for slow growth of their socio-economic development (Kim and Singh, 2002). As a population grows larger, the capability to restore resources for development may grow progressively low. Few people may surely retard economic development as too many people might lack of resources. With a limited Gross national Product (GNP) in less developed countries like India, larger the size of population, the smaller will be the per capita income and the lower the level of living standard. It is hard to increase per capita income quickly, it is necessary either to achieve rapid economic growth or to restrict additional population growth (Tiware, 2000).

With a young population eager to work yet have limited opportunities in traditional sectors, there is a need for new job creators. Entrepreneurship is the act of starting a business to make it commercial. The enterprise owners makes the proper investment to control the operations of a company, and also they forefront the services to the business provides. Small and medium-sized enterprises (SMEs) plays a role of backbone of India's economy contribute

significantly to employment. These businesses are not only generating jobs opportunities for the youth but are also encouraging innovation in sectors like technology, manufacturing, agriculture, and services. Some of the Startups like Flipkart, Zomato, and Ola have already shown the budding of entrepreneurship in creating thousands of jobs for youth.

Entrepreneurship is filled with potential, but many startups fail due to a range of common and avoidable reasons. One major cause is launching too early. In an attempt to be the first to release a product, entrepreneurs often rush into the market without adequate preparation. While staying ahead of trends is important, a premature launch can lead to serious setbacks. Another critical issue is the lack of genuine market interest. If potential customers show little enthusiasm or provide overly cautious or negative feedback, it may signal deeper problems with the business concept. Additionally, many entrepreneurs make the mistake of waiting until after launch to build an audience. A successful business begins forming its customer base early by identifying the right audience and fostering relationships well before going public. Running out of capital is another leading cause of startup failure. Poor financial planning or overestimating early revenue can quickly deplete funds, leaving the business unable to operate. Marketing is also a key area where new businesses fall short. Failing to leverage digital and personalized advertising reduces visibility and prevents meaningful customer engagement.

Moreover, the strength of the team plays a crucial role in a entrepreneurship success. An ineffective or uncoordinated team can cause a venture to collapse, whereas businesses with two or more founders tend to perform better due to shared responsibility and support. Underestimating the competition is another common pitfall, overlooking rival strategies or market presence can leave a startup vulnerable. Finally, a rigid mindset often hinders progress. Enterprises that resist adapting to customer feedback, new technologies, or market trends are likely to fall behind and eventually fail. Flexibility and responsiveness are essential for long-term survival in a constantly evolving business landscape.

Entrepreneurship and Sustainable Development Goals

Sustainable entrepreneurship is opportunity oriented and aims at generating new products, services, production processes, techniques, and organizational procedures which substantially reduce social and environmental impacts which directs in quality of life. Sustainable entrepreneurship, likely to measure its success through its environmental data such as how a product can be more effectively made as a result of creating more sustainable product.

Companies contributing substantially to sustainable development with their core businesses can be called sustainable entrepreneurs (Schaltegger and Wagner 2011). The appearance of the 17 SDGs represents a global strategy aimed at undertaking a spectrum of essential climate, social, economic, and cooperative changes critical for the survival of humanity. By establishing new businesses, entrepreneurship makes a considerable contribution to SDG 8, fostering sustainable economic growth and generating employment opportunities. At the same time, entrepreneurial activities positively impact reducing inequality (SDG 10) and fighting poverty (SDG 1) by providing economic opportunities and empowering communities. Entrepreneur's innovative solutions that address social disparities, generate economic values of business, and energetically contribute to social equity. Therefore, this aligns with the SDG 10 goal of fostering inclusive global community. Additionally, as entrepreneurial business enterprises expand, they uplift local economies, facilitating sustainable livelihoods and sustaining the SDG 1 objective of poverty eradication.

Role of Digital technology in entrepreneurship development

The internet as a digital technology has become the gateway to unmatched global reach and accessibility for various businesses. It has reduced geographical constraints and also strengthening small enterprises the power to indulge into international markets. The role of technologies has transformed traditional workflows, reducing the time and resources needed for routine procedures. This digital technology provide assistance to sales teams to shift their focus and enabling them to dedicate more time to strategic planning and bonding deeper relationships with customers. The digital technology also guides to more personalized customer service, as the data analytics offer insights into customer preferences and behaviours by market analysis, allowing enterprises to interact with individual needs. Digital technology move is saving time and enhancing the quality of business engagements which drives growth through improved customer experiences. Therefore, digital technologies play an increasingly central role in entrepreneurial activities and outcomes within the empire of digital entrepreneurship. However, this shift toward digitization also brings forth new challenges and concerns at the crossroads of technology and entrepreneurship.

Digital technology

Digital technology has been incorporated into entrepreneurship, and it is estimated so that these technologies shape the future of growing digital entrepreneurial firms. Digital technologies

can launch totally new types of innovation in terms of organizational management and processes that are impracticable to exist. The incorporation of digital technologies into entrepreneurship necessitates a focus on outcomes as well as processes, goods, and services. Digital technologies both represent and facilitate the goods and services created by MSME enterprises and permit striking reconfigurations of those products and services. The implementation of digital innovation marked itself in new market mechanisms, bringing the novel values, practices, and procedures.

Digital tool and techniques

1. **Mobile Technology**

Mobile technology plays a vital role in promoting sustainable entrepreneurship practices. It reduces paper usage by enabling digital documentation. Mobile video conferencing reduces the time consumption of travelling, decrease in carbon emissions, promote work-life balance and reduce time utilized for computing. In addition of mobile technology, Internet of Thing (IoT), seniors monitor environmental parameters, optimizing resources usage, Artificial Intelligence (AI) AI-powered chatbots enhances the engagement of customer and provides personalized support. Block chain technology ensures transparency and accountability in supply chain management. Mobile payments reduce the need of cash flow which directs of promoting financial inclusion.

2. **Internet of Thing (IoT)**

IoT plays a major role in driving sustainable development in entrepreneurship, it contribute environmental, economic and social sustainability likes IoT sensors reduces energy utilization, waste and carbon emissions. IoT also monitors and supervises water air and soil quality promoting conservation. Further, IoT facilitates smart waste management systems minimize waste and promote recycling. IoT mechanizes process, reducing operational costs of products and improving productivity. IoT monitor personalization and allows real-time feedback which improves customer satisfaction. It permits business to reach to the communities which are underserved and promote financial inclusion to them. Data driven decision and optimize operations also help business by advanced analytics, AI-powered IoT systems enable predictive maintenance and automatic decision making.

Recent advancements in digital technology, like big data, AI, and 4.0 ma- chines, have completely changed how businesses operate. Digital technology, however, may enhance market

orientation through enhanced market knowledge and operational efficiency through process management optimization (Cenamor et al., 2019). Recent advancements in digital technology, like big data, AI, and 4.0 ma- chines, have completely changed how businesses operate. Digital technology, however, may enhance market orientation through enhanced market knowledge and operational efficiency through process management optimization (Cenamor et al., 2019). Recent advancements in digital technology, like big data, AI, and 4.0 ma- chines, have completely changed how businesses operate. Digital technology, however, may enhance market orientation through enhanced market knowledge and operational efficiency through process management optimization (Cenamor et al., 2019).

Many prominent companies across various sectors have adopted digital transformation to improve efficiency, enhance customer experiences, and support sustainability. For instance, **H&M**, a well-known fashion brand, has implemented technologies like RFID for accurate inventory management, data analytics to refine its supply chain, and a mobile app that connects online and in-store shopping experiences. The company has also introduced automation in its distribution centers to increase productivity. In the entertainment industry, **Netflix** serves as a standout example as its began with DVD rental service and successfully transformed into a leading global streaming platform by investing in advanced technology, original content, and a completely redefined business model. Meanwhile, **GE Healthcare**, a branch of General Electric, has adopted IoT solutions to track and improve the performance of its medical devices. This approach has minimized downtime, enhanced equipment maintenance, and improved customer service, demonstrating how digital innovation can significantly transform even the most traditional industries

Benefits of digital technology

Innovative products and services through digital technology highlights the insightful role of technology on business growth. The fintech sector (companies) stands as a clear example of this profound transformation, where the integration of blockchain and mobile payment technologies has significantly reshaped the landscape of financial services, demonstrating the powerful influence of technology on modern business operations. Digital technologies like AI and machine learning are revolutionizing industries beyond e-commerce by enabling personalized customer experiences in sectors such as healthcare, entertainment, and finance. These innovations not only enhance customer satisfaction but also improve cost efficiency

through data-driven strategies like digital marketing, which offer both affordability and precision. Additionally, strong cybersecurity frameworks ensure transaction integrity and business resilience. By streamlining operations and embracing technological advancements, businesses gain a competitive edge and are better positioned for sustainable growth in an increasingly dynamic marketplace.

Challenges of digital technology

Despite the many benefits, businesses also face significant challenges when adopting digital technologies. Unequal access to digital tools and internet connectivity can create barriers to implementation. A lack of digital literacy among employees often leads to resistance or difficulty adapting to rapidly evolving technologies. Insufficient IT infrastructure, such as outdated hardware or software, can further slow digital transformation. Data protection and cybersecurity risks also raise concerns about safeguarding sensitive information. Moreover, the high cost of implementing new technologies can strain business resources.

Way forward for Leveraging Digital Technology in Sustainable Entrepreneurship

1. **Promote Digital Inclusion:** Ensure equal access to mobile technologies and internet connectivity, especially in underserved or rural areas, to bridge the digital divide and enable inclusive entrepreneurship.
2. **Invest in Digital Literacy Programs:** Train employees and entrepreneurs in digital skills to improve their adaptability and confidence in using emerging technologies like IoT, AI, and mobile tools effectively.
3. **Upgrade IT Infrastructure:** Allocate resources to modernize outdated hardware and software, ensuring that businesses can fully leverage advanced digital solutions without performance bottlenecks or security vulnerabilities.
4. **Adopt Scalable, Sustainable Technologies:** Utilize mobile solutions, AI-powered tools, IoT, and blockchain to reduce paper usage, lower emissions, improve supply chain transparency, and enhance customer engagement—all while maintaining cost-effectiveness.
5. **Strengthen Data Protection and Cybersecurity:** Develop strong cybersecurity protocols and regulatory compliance measures to protect sensitive data and build trust with customers and partners in digital environments.

6. **Encourage Government and Private Sector Support:** Advocate for policies and public-private partnerships that support the funding, adoption, and integration of digital technologies in small and medium enterprises (SMEs), especially for green innovation and sustainability goals.

Conclusion

In conclusion, digital technology has emerged as a powerful driver of sustainable entrepreneurship, offering innovative solutions to economic, social, and environmental challenges. By enabling efficiency, expanding market reach, and fostering inclusive growth, technologies like AI, IoT, mobile platforms, and blockchain are reshaping traditional business models. However, to fully realize these benefits, it is essential to address challenges such as digital inequality, lack of infrastructure, and cyber security risks. Promoting digital literacy, upgrading IT systems, and supporting SMEs through collaborative efforts can bridge these gaps. With the right strategies in place, digital entrepreneurship can significantly contribute to sustainable development and inclusive economic progress.

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THE STRATEGIC ROLE OF SWEETCORN IN PERIURBAN ZONES

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Introduction

Maize, commonly referred to as corn, ranks among the most significant and extensively cultivated cereal crops globally. Its adaptability and versatility render it a fundamental food source in numerous nations and a crucial element of worldwide agriculture. Various maize types, such as dent, flint, pop, waxy, and floury, are tailored for specific uses based on their grain composition. Specialty varieties, including sweet corn, popcorn, baby corn, and high-oil corn, hold substantial market potential both internationally and within India. (Dass *et al*., 2012). There is considerable potential for growth in Indian agriculture, particularly due to evolving food preferences and agricultural practices. Sweet corn, in particular, stands out as a vital crop, renowned for its sweet and tender kernels that distinguish it from other maize varieties. In recent years, its production has surged, establishing it as an essential crop for both fresh consumption and the food sector.

Notably, there has been an increasing demand for maize, including sweet corn, in developing nations, largely fueled by its applications in animal feed and human consumption (FAO, 2023). It is a common vegetable crop, and its popularity has grown in North America, Europe and Asia. Around 40 per cent of the corn used in manufacturing is frozen, while the rest is canned. The USA ranks number one in sweet corn production, followed by Japan, Canada, France and Taiwan. Nowadays, it is being consumed in frozen or canned form on a large scale in India as well. Unlike regular maize, sweetcorn has been selectively bred to have a higher sugar content, making it particularly desirable for consumption. It is distinguished from other vegetable

corns by the presence of one or more recessive alleles within the maize endosperm starch synthesis pathway. This results in reduced starch content and increased sugar concentration when consumed fresh. This hybridized variety is more specifically bred to increase the sugar content with high yield per plant, even when the husks are removed, making it a highly productive and valuable crop. The breeding process focuses on maximizing both sweetness and productivity, which has made sweetcorn a popular choice for both large scale commercial farming and home gardening wherein getting a substantial harvest from a small planting area. Its versatility allows it to be used in a variety of culinary applications, from fresh eating to processed foods. As The State of Food and Agriculture 2023 revealed, agrifood systems activities generate significant benefits for society, but also have negative impacts on economic, social and environmental sustainability.

The quantified hidden costs of agrifood systems amount to around 10 percent of global gross domestic product. Therefore, strategic action is necessary, and all agrifood systems actors – from producers and agribusinesses to consumers and governments – have a crucial role to play (source: The State of Food and Agriculture 2024). The importance of sweetcorn as a viable crop within periurban areas (zones that lie between urban and rural environments) represents a strategic resource that can enhance nutritional food security, economical and sustainable livelihoods, and environmental benefits. Nowadays, there is an emphasis on the diversification of cropping system and finding alternative crops for the changing climate and depleting groundwater levels in India, especially in the context of Haryana and Punjab. So, diversification and value addition through cultivation of sweet corn for vegetable purposes is emerging as a highly profitable activity (Dass et al., 2012). Therefore, it is considered to be a profitable crop for peri-urban farmers like areas adjacent to NCR regions specially Sonipat (a district of Haryana adjacent to New Delhi). It is not just a crop but a vital component of periurban food systems, offering nutritional, economic, sustainable and environmental benefits. Its cultivation can help bridge the gap between urban food demands and rural agricultural practices, making it a crucial player in the sustainability and resilience of food systems in transitional areas. Thus, the cultivation of sweetcorn in periurban areas is a viable option in terms of its nutritional value, economical value, livelihood security and environmental sustainability.

Sweet corn is a highly nutritious and versatile vegetable that provides essential nutrients, making it a valuable addition to a balanced diet. It is packed with vitamins, minerals, fiber, and

antioxidants that support overall health and wellbeing. Whether eaten fresh, boiled, grilled, or added to various dishes, sweet corn provides both taste and nutrition, making it a staple in many diets worldwide. It also contributes to dietary diversity, especially in urban areas where access to fresh produce may be limited. It is a naturally gluten-free food, making it a great option for people with gluten intolerance or celiac disease. It is also pesticide free as it is covered beneath the husk. It is a rich source of dietary fiber, vitamins (particularly B vitamins), antioxidants and minerals make it a wholesome and balanced food choice for people of all ages. It contributes significantly to dietary diversity in urban diets, particularly in areas where access to fresh produce may be limited. Here's an overview of its nutritional profile and significance.

Nutrient	Amount per 100g of Cooked Sweetcorn	% Daily Value*	Significance
Calories	96 kcal	5%	Provides energy for bodily functions.
Carbohydrates	21g	7%	Source of fiber and natural sugars for energy.
Fiber	2.7g	11%	Aids digestion, helps control blood sugar.
Protein	3.4g	7%	Supports muscle repair, immune function.
Fat	1.5g	2%	Low fat content, mainly unsaturated fats beneficial for heart health.
Vitamin C	6.8mg	8%	Important antioxidant, supports immune health.
Vitamin B6	0.1mg	8%	Vital for brain health and metabolic functions.
Folate	46mcg	12%	Essential for DNA synthesis, particularly important during pregnancy.
Magnesium	37mg	9%	Supports muscle and nerve function,

			bone health.
Potassium	270mg	6%	Helps maintain blood pressure, supports muscle function.
Iron	0.5mg	3%	Important for oxygen transport in blood.
Antioxidants	Varies	N/A	Contains lutein and zeaxanthin, which support eye health.

Source :USDA Food Data Central.

Farmers can increase their income by growing several crops of sweet corn in regions near cities like Sonipat or other urban areas bordering the NCR zone. These corns are profitable for peri-urban agriculture because of their high market value. As a result, they guarantee maize farmers greater revenue. It also ensure a stable and sufficient food supply for the increasing population, reducing food insecurity and improving overall economic stability. It can yield several harvests in a year because to its very short growing season, which can generate a consistent income. Additionally, there is a great demand for it in both metropolitan and local markets. Periurban agriculture, particularly sweet corn production, provides job opportunities by supporting both full-time and seasonal labor, improving the standard of living in nearby areas. Sweet corn can be harvested in 70–80 days, as immature cobs are a more economical product. After harvesting the cobs, the young plants serve as nutrient-rich green fodder high in starch, making them a good alternative to sorghum and other fodder crops. The proximity to metropolitan markets reduces transportation costs and spoilage, allowing farmers to earn higher prices and increase their income.

It might also be used as a backup crop in the event of crop failure. Thus, sweet corn is both a cash crop and a catch crop. Growing sweet corn contributes to agricultural diversification. Economic diversification results from reducing reliance on a single crop, which can help stabilize farmers' incomes and make them more resilient to adverse weather conditions or market fluctuations. It contributes to land use efficiency because sweetcorn's comparatively high yield per unit of land makes it an efficient crop in periurban settings where land may be scarce and costly. Growing sweetcorn can benefit local food systems, farmers' markets, social ties, and community-supported agriculture projects. Growing sweet corn can be used as an educational

tool to teach farmers, students, or community members about environmentally friendly farming techniques and the benefits of nutritious food.

Sweet corn is a good choice for periurban farmers because it grows well in different conditions and requires fewer resources. Its ability to adapt helps improve soil health and supports biodiversity in these areas. Periurban sweet corn farming provides a steady supply of fresh and healthy food, helping to improve urban food security. This is especially important for low-income communities that rely on affordable, locally grown food. By reducing dependence on distant food sources, periurban sweet corn farming can protect cities from supply chain disruptions, rising prices, and food shortages.

Discussion:

Overall, sweetcorn can be a valuable crop in periurban areas, contributing to economic stability, food security, and sustainable land use while also supporting community and cultural connections. However, policies that support periurban agriculture, such as access to land, water, and infrastructure, can amplify the benefits of sweetcorn cultivation. Urban planners and policymakers need to recognize the potential of periurban areas as critical zones for sustainable food production, aligning agricultural practices with broader urban development goals. Sweetcorn is more than just a crop; it represents a strategic resource in periurban food systems that can enhance food security, sustain livelihoods, and contribute to environmental sustainability. By growing sweet corn, periurban areas can help build strong and reliable food systems for cities.

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AI-DRIVEN INNOVATIONS IN SEED SCIENCE: TOOLS, TECHNIQUES AND APPLICATIONS

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Introduction

Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are able to think, learn, and act intelligently. It enables them to perform tasks that typically require human- like perception, decision-making, and interaction. The development of Internet of things (IoT) will lead to detecting, analyzing, classifying diseases, phenotypic and genomic selection in seed in agricultural crops without human intervention in the decision making. Artificial Intelligence (AI) is revolutionizing various fields, and in agriculture, it is having a profound impact on genomic and phenotype selection. Genomic selection, which involves identifying desirable traits in plants or animals through genetic data, is a powerful tool for improving agricultural productivity and sustainability.

AI, particularly machine learning (ML) algorithms, has the ability to process large datasets of genomic information, making it easier to predict the genetic potential of individuals and to select optimal breeding candidates. AI models can analyze complex patterns in genetic sequences and identify correlations between genes and traits of interest, such as disease resistance, yield, and quality. In the realm of phenotype selection, AI is being applied to optimize the selection of desirable phenotypic traits, such as size, color, growth rate, or drought tolerance. Traditionally, phenotype selection has relied heavily on visual inspection and physical measurements, but AI enables more precise, data-driven evaluations. Computer vision, combined

with AI algorithms, allows for automated analysis of plant or animal traits from images or sensor data, reducing the time and labor needed for manual assessment.

This is especially beneficial in large-scale breeding programs where data accuracy and efficiency are crucial. By integrating AI into genomic and phenotype selection processes, breeders can make faster and more informed decisions, accelerating the development of improved crop varieties or livestock breeds. Furthermore, AI can help tailor breeding strategies to specific environmental conditions, making it possible to create varieties that are better adapted to climate change. As AI continues to evolve, its role in genomic and phenotype selection will be in advancing precision agriculture and enhancing food security globally. The development of Internet of things (IoT) will lead to detecting, analyzing, classifying diseases, phenotypic and genomic selection in seed in agricultural crops without human intervention in the decision making.

1. Computer Vision

Computer vision is a subset of AI that allows systems to interpret visual data from seed images and videos. It uses deep learning and image processing algorithms to detect seed features and abnormalities. In seed science, computer vision is applied for:

- Seed size, shape, and color analysis for varietal identification and grading.
- Real-time monitoring of seed germination and seedling emergence.
- Defect and disease detection, including fungal infections and mechanical damage.

2. Deep learning

2.1. Galaxy Machine Learning Community

The Galaxy ML Community promotes integration of machine learning algorithms into biological data analysis workflows. It is particularly useful in high-throughput seed phenotyping and genomic data interpretation. AI models under Galaxy can be trained for trait prediction, genomic selection, and pattern recognition in seed datasets, supporting accelerated breeding efforts.

2.2 Bioconductor Packages (2001)

The Bioconductor project, established in 2001, provides open-source R packages tailored for genomic data analysis. In seed research, these packages are extensively used for analyzing transcriptomic changes during germination and seed development. Packages like edgeR, limma and DESeq2 support gene expression studies and facilitate seed quality trait discovery.

2.3 GAPIT – Genome Association and Prediction Integrated Tool (2012)

GAPIT is a machine learning-integrated R package used for genome-wide association studies (GWAS) and genomic prediction. It enables:

- Marker-trait association discovery,
- Statistical modeling with principal component analysis (PCA),
- Visualization through informative graphs and tables,
- Evaluation of experimental design efficiency.

GAPIT's ML-enhanced algorithms make it a powerful tool for associating genetic markers with seed quality traits.

2.4 DeepGS – Deep Genomic Selection (2017)

Developed in 2017, DeepGS is a deep learning framework dedicated to genomic selection. It effectively handles large-scale genomic data to predict breeding values and trait outcomes. DeepGS outperforms traditional models in complex trait prediction due to its ability to model non-linear relationships in genotypic data. It is particularly beneficial in seed vigor, yield potential and stress resilience prediction, thus expediting the breeding cycle.

3. Machine Learning Frameworks in Seed Phenotyping

3.1 TensorFlow (2015) developed by Google Brain, is a leading open-source machine learning framework utilized in seed trait prediction. Leveraging computational graphs, TensorFlow facilitates deep learning model construction for tasks such as germination classification and seed vigor estimation. It supports scalable development for both researchers and developers.

3.2 PyTorch (2016) introduced by Facebook's AI Research Lab (FAIR), provides a dynamic computational graph (define-by-run), allowing greater flexibility for real-time model adjustments. In seed science, PyTorch is popular for its intuitive API and efficient deployment in neural network-based seed imaging models.

3.3 H2O.ai (2012) offers a cloud-based machine learning platform that integrates ensemble learning methods random forests, gradient boosting machines, and deep neural networks making it suitable for predictive modeling in genomic and phenotypic datasets.

3.4 DL-GWAS (2016) integrates deep learning with Genome-Wide Association Studies (GWAS), offering improved prediction of complex seed traits such as drought tolerance and vigor. Using artificial neural networks, DL-GWAS captures nonlinear genotype-phenotype associations, outperforming traditional linear models.

4. AI-Driven Phenotyping and Trait Analysis Tools

4.1 PhenoSeeder (2016) automates phenotypic trait prediction by integrating high-dimensional genomic data (e.g., SNPs) with morphological features. Utilizing random forest algorithms, it predicts growth characteristics, germination performance and disease resistance in seeds.

4.2 Phenobot 4.0 (2023) employs deep learning techniques to interpret high-throughput plant and seed phenotypes. It measures biochemical and morphological traits such as chlorophyll content, sugars, malic acids, tartaric acid and mineral composition, enhancing precision in breeding programs.

4.3 SeedGerm (2022) uses gradient boosting and neural networks to predict germination rates based on both genetic and environmental inputs. Time-lapse imaging is used to monitor seedling emergence, integrating AI for dynamic assessment.

4.4 PhotosynQ combines hardware sensors and mobile applications to analyze photosynthetic activity and metabolic status in seeds. It measures stress responses and chlorophyll fluorescence to differentiate seed batches based on physiological performance.

5. Genomic Data Analysis Tools

5.1 TASSEL (2007) and PLINK (2007) are robust platforms used in association mapping and linkage analysis. TASSEL integrates population structure and LD mapping, while PLINK provides efficient quality control and association tests in GWAS.

6. Imaging Technologies in Seed Science

6.1 Hyperspectral Imaging (2000) captures data across visible to near-infrared spectra, allowing identification of biochemical and physical seed properties. Platforms like Specim FX and BaySpec offer pixel-level analysis of seed composition.

6.2 Infrared Thermography (1960–2000) is a non-invasive method for detecting temperature differentials in seeds. It is useful for stress and disease analysis by visualizing heat signatures indicative of metabolic changes.

6.3 Fluorescence Imaging (2002) evaluates seed viability by detecting light emissions from fluorophores excited under specific wavelengths. It supports early-stage germination analysis and vigor prediction.

6.4 Multispectral Imaging with UAVs (2020) offers field-scale phenotyping through aerial platforms. UAV-mounted multispectral cameras capture high-resolution data on germination, emergence, and crop health, supporting real-time decision-making.

7. Image Analysis Software and Open-Source Platforms

7.1 ImageJ (2010), a widely used image analysis platform, is enhanced with AI plugins such as DeepImageJ, enabling advanced classification and segmentation of seed images.

7.2 PlantCV (2016) is a Python-based toolkit designed for high-throughput plant and seed image analysis. It includes AI modules for feature extraction, classification, and phenotype quantification.

8. IoT and Smart Sensing for Seed Monitoring

IoT Sensors facilitate real-time data acquisition on temperature, humidity, and light conditions influencing seed storage and germination. The integration of IoT with AI enhances adaptive monitoring and predictive analytics.

Conclusion

Artificial intelligence is transforming seed science by enabling precise and rapid assessment of seed quality, germination potential, and breeding value. From deep learning-based image analysis to genomic data mining, AI technologies are streamlining seed research and accelerating innovation. Despite challenges in data quality and implementation, AI holds immense potential to boost agricultural productivity and sustainability. Continued integration of AI tools will be essential for future-ready, climate-resilient, and high-yielding seed systems.

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NATURE'S FLAVORFUL POWERHOUSE FROM FARM TO TABLE - ONION FARMING AND HEALTH

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Introduction

Onions are the most commonly grown vegetables of the Allium family. They are known as Vaengayam (Tamil), Savala (Malayalam), Erulli (Kannada), Nirulli (Telugu), Pyaz (Hindi), and Piyaz (Bengali). Other similar vegetables are garlic, leek, and shallot. The onion plant has blue-green leaves, and the bulb at the bottom swells after a certain period. Onions are grown and consumed all over the world. They are usually served boiled. They can also be eaten raw and are used in pickles, sambars, and chutneys. Onions have a strong flavor and a sharp, pungent taste. It can be cultivated in different climates (temperate, tropical, and subtropical).

Onions are delicious vegetables known for more than their texture and flavor. It is known for its strong, sharp, pungent taste. Onions are full of vitamins B6 and C, iron, and potassium. They contain allium and allyl disulfide. These compounds can reduce the risk of cancer, maintain healthy blood sugar, calm inflammation, and treat infections.

The ancient origin of the onion goes back to the western and eastern parts of Asia. There are many types of onions in the world, which means they were probably cultivated all over the world at the same time. According to information, onions were used in China as early as 5000 BC. mainly due to the durability of onions in transportation and storage. The ancient Egyptians respected this vegetable, considering its spherical shape and concentric rings as a symbol of eternal life. Onions were also used in ancient Egyptian burials. The medical records of the Charaka Samhita (up to the 6th century BC) mention onion as a medicinal plant. Even a Greek physician from the 1st century AD (Pedanious Dioscorides), the father of pharmacognosy

documented the medicinal use of vegetables. It was the first European settler who brought onions to North America.

Different types of onions?

Onions are so widely used that almost everywhere in the world, onions are added to all culinary dishes. There are several types of onions:

Yellow onions - They have ivory white flesh surrounded by thick brown skin. They have a strong and sulfurous smell.

Sweet onions - These have a lighter, less opaque skin that surrounds the larger, slightly fattier body of the vegetable.

White onions - They have a papery white skin and are milder and sweeter than their yellow counterparts.

Red onions - These are mild and sweet enough to eat raw. The skin and flesh are deep magenta.

Shallots - These are smaller and have brown skin and purple flesh.

Green onions - These are immature bulbs that have not yet formed into bulbs.

Leek - It is shaped like an overgrown onion (a long-necked onion with a small bulb) and is often used in sauces and soups.

Small onion (*Allium cepa* var. *aggregatum*)

The scientific name of the small onion is (*Allium cepa* var. *aggregatum*) and belongs to the Alliaceae family. Shallots/small red onions/scallions have a special shape that makes them different from other members of the onion family. Shallots are prepared in thin layers. This allows them to mix well with sauces and dips that taste somewhere between garlic and onion. Shallots have a delicate and sweet taste with a touch of sharpness. Small red onions are rich in vitamins and minerals. 100 grams of shallots have 72 calories, 16.8 g of carbohydrates, 7.9 g of sugar and 2.5 g of protein.

Soil and season

Grows well in red loam to black soil with good drainage. It works well in a soil pH range of 6-7 without extremes of heat and cold. Onions are usually sown in April-May and October-November. It needs sufficient soil moisture during the growing season, but heavy rains occur during the germination and formation of bulbs, which affects the growth of crops.

Preparation for nursery

This is the most common method of irrigated crops because it gives high yields and large

bulbs. In the plains, seeds for the rabi harvest are sown in October-November. In the mountains, seeds are sown from March to June. The seeds are first sown in a well-prepared bed with a width of 90-120 cm, a height of 7.5-10.0 cm, and a length as per the requirement. The ratio of plant area to main field is approximately 1:20. The seed rate varies from 8-10 kg/ha. Seedlings of 15 cm height and 0.8 cm neck diameter are ideal for planting and this can be achieved in 8 weeks. However, it varies from 6 to 10 weeks, depending on soil, climate, and rainfall. It is customary to cover the seedlings during planting when they have emerged.

Field preparation and planting

Plow the soil finely and form ridges and furrows every 45 cm. Sow the bulbs on both sides of the ridge at a distance of 10 cm from each other. Water when seedlings are planted, and on the third day, and after every 30 cm, every week, or 120 cm, raised beds are formed and side beds are placed in the center of each box. Seedlings are planted in rows with a distance of 20 cm and 12 cm between plants. Six rows are planted in each bed, so 55,560 plants can be grown on one hectare. Watering is done after planting or planting bulbs. Complete irrigation is necessary to maintain consistent moisture. Stop watering 10 days before harvest.



Manure and fertilizers

Farm yard manure 25 t/ha should be applied one month before transplanting, Azospirillum 2 kg and Phosphobacteria 2 kg/ha and fertilizers of N 30 kg, P 60 kg, and K 30 kg/ha can be applied as basal and on the 30th day of sowing 30 kg N/ha can be given. For fertigation, 75% of the recommended total dose of superphosphate ie, 285 kg/ha as the main dose. Azospirillum and Phosphobacteria, each @ 2 kg/ha with FYM 50 kg and Neem cake @ 100 kg, are applied before the last ploughing.

Recommended water-soluble fertilizers for small onions

Water-soluble fertilizers are excellent for small onion cultivation as they provide quick nutrient absorption and boost plant growth efficiently.

- 19-19-19 (Balanced formula for early growth)
- 12-61-00 (High phosphorus for root development)
- 13-40-13 (For bulb initiation and strengthening)
- 00-52-34 (High potassium for bulb firmness and disease resistance)
- Calcium Nitrate ($CaNO_3$) – Improves bulb quality and prevents disorders.
- Magnesium Sulphate ($MgSO_4$) – Enhances photosynthesis and chlorophyll production.
- Boron (Boric Acid) – Essential for bulb formation and structure.
- Zinc Sulphate – Supports enzyme activities and plant metabolism.





Foliar spray

- DAP (Di-Ammonium Phosphate) solution – Promotes early root growth.
- Potassium Nitrate (KNO_3) – Strengthens bulb size and storage quality.

Apply fertilizers using drip irrigation or foliar spray for optimal absorption. Use low concentrations (0.5–1% solutions) to avoid leaf burn. Ensure consistent moisture for improved

nutrient uptake. Apply micronutrients at critical growth stages, such as bulb formation and maturation.

Integrated pest and disease control

• Cultivation of two rows as barrier plants at the border of the field.

• Selection of healthy onion seed bulbs.

• Soil application *of Pseudomonas fluorescens* (1.25 kg/ha) + *Trichoderma viride* (1.25 kg/ha) + AM Fungi (VAM) (12.5 kg/ha) + Azophos (4kg/ha) + Neem cake 250 kg/ha.

• Installation of yellow sticky traps 12 nos./ha for thrips and leaf miners.

• Installation of pheromone traps 12 nos/ha for cutworm

• *Pseudomonas fluorescens* (5 g/l) + *Beauveria bassiana* (10 g/l) spray on 30 DAP and Azadirachtin 1% (2 ml/l) spray on 40 DAP.

• In case of leaf spot, spray Mancozeb 2 g/l or copper oxychloride 2.5 g/l and add Teepol 0.5 ml/l to the spray liquid.

• Application of Profenofos (2 ml/l) or Dimethoate (2 ml/l), or Triazofos (2 ml/l) as needed to control thrips/leaf breakers/cutworms.

• Tebuconazole (1.5) ml/l or mancozeb (2 g/l)/zineb (2 g/l) is required to manage purple blotch disease.

Harvest

The duration of the crop is 70 to 90 days. The yield of onion ranges from 12-16 t/ha which depend on the duration and variety of crop. Harvesting is done by pulling out plants when tops are drooping but still green. During the hot days when soil is hard, bulbs are pulled out with a hand-hoe. Clean and dry the bulbs for 4 days in shade soon after harvest.

Health benefits of onions

- Loaded with nutrients.
- Beneficial for heart health.
- Contains antioxidants and anti-cancer compounds.
- Helps control blood sugar.
- Increase bone density
- They have antibacterial properties
- Promote digestive health.

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CLIMATE-SMART AGRICULTURE: A PATHWAY TO SUSTAINABLE FARMING

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Introduction

Climate change has dragged Indian agriculture to crossroads and left it to decide a right path between maximization and sustainability. The production variables leading to a very critical situation for researchers, extension practitioners and especially farmers. The ways and techniques designed to combat, mitigate and adapt risks generated due to climate are discussed here. Climate Smart Agriculture is nothing but the approach for developing agricultural strategies to secure sustainable food security under climate change. It is an approach that helps to guide actions needed to transform and reorient agricultural systems to effectively support development and ensure food security in a changing climate (FAO, 2013). Climate-smart agriculture (CSA) involves implementing technologies and practices that increase agricultural productivity, enhance resilience to climate change impacts, and reduce greenhouse gas emissions(FAO, 2010). CSA aims to achieve "better production, better nutrition, a better environment, and a better life for all". Coined by the Food and Agriculture Organization (FAO), CSA is a triple-win strategy designed to secure food security while addressing climate change. Climate-smart agriculture is a pathway towards development and food security built on three pillars: increasing productivity and incomes, enhancing resilience of livelihoods and ecosystems and reducing and removing greenhouse gas emissions from the atmosphere (World Bank, 2021).

The three pillars of CSA

Productivity: CSA aims to sustainably increase agricultural productivity and incomes from crops, livestock and fish, without having a negative impact on the environment. This, in turn,

will raise food and nutritional security. A key concept related to raising productivity is sustainable intensification

Adaptation: CSA aims to reduce the exposure of farmers to short-term risks, while also strengthening their resilience by building their capacity to adapt and prosper in the face of shocks and longer-term stresses. Particular attention is given to protecting the ecosystem services which ecosystems provide to farmers and others. These services are essential for maintaining productivity and our ability to adapt to climate changes.

Mitigation: Wherever and whenever possible, CSA should help to reduce and/or remove greenhouse gas (GHG) emissions.

Objectives of Climate-Smart Agriculture

- **Enhance Agricultural Productivity:** Ensure sustainable increases in crop, livestock, and fish productivity to support food security and income.
- **Build Resilience and Adaptation:** Strengthen the capacity of farming systems to cope with climate variability and extreme weather.
- **Reduce Greenhouse Gas Emissions:** Lower emissions from agriculture and enhance carbon sequestration where possible.

Key Technologies and Practices in CSA

1. Drought-Resistant Crop Varieties: Developing and utilizing crops that can withstand water scarcity and extreme temperatures.

2. Smart Irrigation Systems: Employing efficient irrigation techniques like drip irrigation and precision irrigation to optimize water usage and minimize water wastage.

3. Cover Crops: Planting non-cash crops to improve soil health, suppress weeds, and prevent erosion.

4. Crop Diversification and Rotation: Growing multiple or alternative crops improves resilience and reduces pest/disease cycles. Encourages a shift from monocultures to sustainable cropping patterns.

5. Climate-Smart Livestock Practices: Improved fodder management and silage storage for dry periods. Manure management systems to reduce methane emissions.

6. Agroforestry: Integrating trees and shrubs into farming systems to enhance soil health, biodiversity, and carbon sequestration.

7. Precision Farming and ICT Tools: Utilizing technology like GPS, sensors, and drones to optimize resource use (water, fertilizers, pesticides) and improve crop yields.

8. Organic Farming and Natural Farming: Encourages low-input, ecological farming that maintains long-term soil and environmental health.

Benefits of Climate-Smart Agriculture

- **Increased Productivity and Income:** CSA practices can lead to higher crop yields and livestock production, improving farmers' incomes and food security.
- **Enhanced Resilience to Climate Change:** CSA technologies and practices help farmers adapt to the impacts of climate change, such as droughts, floods, and extreme temperatures.
- **Reduced Greenhouse Gas Emissions:** CSA practices can help reduce greenhouse gas emissions from agriculture, contributing to climate change mitigation.
- **Improved Soil Health and Biodiversity:** CSA practices promote healthy soils, enhance biodiversity, and create more resilient ecosystems.
- **Sustainable Livelihoods:** CSA can contribute to sustainable livelihoods by improving food security, reducing poverty, and creating economic opportunities in rural areas.
- **Climate Change Adaptation and Mitigation:** By adopting CSA practices, farmers can adapt to the impacts of climate change while also contributing to global efforts to reduce greenhouse gas emissions.

Institutional Support for CSA in India

- **NICRA (National Innovations on Climate Resilient Agriculture)**: Launched by ICAR to promote CSA in vulnerable regions.
- **Krishi Vigyan Kendras (KVKs)**: Demonstrates CSA technologies at the grassroots level.
- **State Climate Action Plans**: Includes strategies for promoting climate-resilient agriculture.
- **Paramparagat Krishi Vikas Yojana (PKVY)**: Promotes organic farming practices.
- **PM-KUSUM**: Supports solar energy in agriculture, reducing fossil fuel dependence.

Climate Smart Agriculture - Indian Initiatives:

To meet the challenges posed by climate change on the agricultural system, India has accorded high priority in understanding the impacts of climate change and developing adaptation

and mitigation strategies. National Action Plan on Climate Change (NAPCC) established during the year 2008 and has identified agriculture as the priority area of eight National Missions in India. National Adaptation Fund for Climate Change (NAFCC) was established in August, 2015 to meet the cost of adaptation to climate change for the State and Union Territories of India that are particularly vulnerable to the adverse effects of climate change. The projects under NAFCC prioritize the needs that build climate resilience in the areas identified under the SAPCC (State Action Plan on Climate Change) and the relevant Missions under NAPCC.

Way Forward

1. Farmer Training and Capacity Building through KVKs and FPOs.
2. Public-Private Partnerships for technology diffusion and input supply.
3. Digital Climate Services to deliver timely advisories.
4. Incentives and subsidies for adopting low-emission technologies.
5. Integrating CSA into agricultural policies, education, and rural development programs.

Conclusion

Climate-Smart Agriculture is more than a set of practices — it is a holistic framework for sustainable farming in a changing climate. As food security becomes increasingly threatened by climate shocks, CSA offers a promising path toward a resilient, productive, and environmentally sustainable agricultural future. With the right support, India's vast and diverse farming community can lead the way in building climate-resilient food systems.

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GREEN ENTREPRENEURSHIP

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Abstract

Green entrepreneurship refers to the creation and development of business ventures that are environmentally responsible and economically viable. These ventures aim to address environmental challenges such as climate change, resource depletion, pollution and biodiversity loss, while generating profit and employment. In the context of sustainable development and the circular economy, green entrepreneurship plays a critical role in redefining the business landscape by integrating environmental goals into entrepreneurial strategies.

Introduction

The green entrepreneurship identifies new business opportunities, develops their ideas, turns those ideas into reality and launches and supports the business in order to generate revenue. India has been quickly utilizing its natural resources in order to foster rapid industrialization and economic development. India needs green entrepreneurs who can serve as change agents and foster sustainable economic growth by combining innovation and sustainability.

Income increase per capita, Improvement Changes in lifestyle, higher education levels and increased understanding of environmental issues may all contribute to this change. India's paradigm change in consumption habits has resulted in the development of green markets, which offer entrepreneurs a great deal of room and potential for creating and developing green products as well as utilizing green methods.

In addition to meeting the changing consumer demand for sustainable goods, green entrepreneurship also aims to support and lead the way toward long-term sustainable development. Green entrepreneurs are entrepreneurs that recognize the relationship between innovation and sustainability and gain a competitive advantage by concentrating on and marketing environmentally beneficial goods. Green products are created to minimize the use of natural resources, eliminate hazardous waste materials that may be harmful to the environment and human health, recycle waste materials, and use less energy.

Factors Enabling Green Entrepreneurship

It is crucial to thoroughly examine the elements and circumstances that affect green entrepreneurship and the impact of formal and informal networks on the performance of green small and medium enterprises (SMEs).

Governments must create favorable policy environments, lessen or eliminate corruption to make green entrepreneurship more appealing, and teach consumers about the value of buying sustainable products in order to encourage it. People are more likely to make green purchases if they are educated about the environment. Green entrepreneurship is to raise environmental awareness, which will ultimately cause people to buy green products regardless of their higher costs.

Venture capitalists will be more inclined to invest in a green entrepreneur if they can communicate a trustworthy signal to investors, which can be accomplished by not only using green technologies but also by placing the company in the green industry. People who care about the environment are an asset to the entire green entrepreneurial ecosystem and environmental principles have a beneficial effect on the success of green business endeavors. By incentivizing investments in environmentally friendly business practices and easing obstacles to the development of a sustainable market environment in India, there is a need to encourage green entrepreneurship.

In order to foster a willingness and readiness to start these, green businesses need more multidimensional and multi-level help than commercial companies do. The government should establish conducive conditions, such as financial incentives, knowledge improvement initiatives, and information sharing and information exchange. A supportive environment is necessary for green programs and entrepreneurship to flourish, flexible, interactive, and connected and whose constituent parts are not clearly defined. In India, the significant difficulties facing green

entrepreneurs include a shortage of funds, a lack of access to information resources, a lack of legal knowledge and a lack of managerial and technical skills.

Research Objectives and Methodology

The goal of this research is to examine and understand how green entrepreneurship has evolved in India. The following aims have been established:

- To clarify the term 'green entrepreneur'.
- To investigate the factors that support green entrepreneurship in India.
- To provide recommendations for enhancing green entrepreneurship in India.

This research into the idea of 'green entrepreneurship' by utilizing various secondary literature resources, including scholarly articles, websites of green businesses and interviews with green innovators found in both print and online media. A conceptual framework is developed that assesses the relationships among social, environmental and economic elements in influencing green entrepreneurship within the Indian market.

Kinds of Eco-Friendly Business Initiatives

- Renewable Power Plans: Include solar panel installation, biofuel production and wind energy development.
- Waste management and recycling processes: Includes firms that recycle plastic, compost organic trash or handle electronic waste
- Agriculture for Sustainable Development: Organic farming, agroforestry, hydroponics and aquaponics.
- The ecotourism industry and eco-products: The production of sustainable crafts, eco-resorts, and bamboo-based products.
- The Green Consulting: Assessing environmental impact, facilitating carbon credits and providing sustainability certificates.

Characters of Green Entrepreneurs

Green business owners are:

- Dedicated to sustainability and with a clear vision.
- Mindful of the environment Open to experimenting with eco-innovation.
- Concentrating on long-term gains.
- Adjusting to shifts in the industry and environmental legislation.

Importance of Green Entrepreneurship

Green business contributes to

- Lowering environmental degradation and pollution
- Encouraging the development of novel clean technologies
- Making employment that is both environmentally friendly and sustainable
- Enhancing livelihoods, particularly in rural regions
- Increasing the efficiency of energy and resource use promoting climate policies and the Sustainable Development Goals (SDG) of the government.

Conclusion

The study of green entrepreneurship, which employs green technologies in production and redesigns supply chains to better address the demands of greenness, generate green jobs and increase demand for green products, ultimately contributing to sustainable development and a greener economy. It is necessary to establish a culture that fosters entrepreneurs' awareness of the possibilities that come from adopting green business models, encourages green investments and eliminates the obstacles in the way of launching and maintaining green businesses. Institutional assistance is necessary to give green entrepreneurs financial and technical assistance. In comparison to commercial firms, green businesses need more multidimensional and multilevel support, the government should establish favorable conditions for launching viz., information sharing, financial incentives, information exchange and programs to improve knowledge.

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GREEN MARKETING

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Abstract

Rising global environmental concerns are reshaping consumer behavior and market dynamics. Green marketing, which aims to promote items that are environmentally responsible, has grown in importance. Companies are exploring innovative strategies to demonstrate their sustainability commitments. Particularly in India, green marketing has evolved from a niche concept to a critical tool for fostering sustainable growth and global development.

Introduction

Green marketing refers to the promotion and sale of products or services that are environmentally friendly, sustainable, and socially responsible. It involves developing and marketing products in a way that minimizes negative environmental impact and often highlights a company's commitment to sustainability.

1. Understanding the Foundations of Green Marketing

Henion and Kinnear first defined ecological marketing as marketing efforts that either contribute to or solve environmental issues. Expanding on this, Fuller (1999) introduced sustainable marketing as a method of designing, pricing, promoting and distributing products in a way that (1) meets consumer needs, (2) supports business objectives and (3) remains in harmony with natural ecosystems.

2. Why Green Marketing Is Essential Today

Environmental challenges like global warming and ozone depletion have increased the

need for eco-conscious practices. Individuals and organizations alike seek healthier for sustainable lifestyles. While profitability is still central to business strategy, the environmental cost of doing business has pushed companies toward more responsible practices. This shift has also encouraged the adoption of Corporate Social Responsibility (CSR) initiatives.

3. Green Consumer

Green buyers actively look for goods that are less detrimental to the environment. They consider how products are produced, the materials used and the overall environmental and societal impact. Their preferences typically include:

- **Sustainable materials** - biodegradable, recyclable, or natural
- **Energy efficiency** - electric vehicles or low-energy appliances
- **Ethical production** - cruelty-free and chemical-free goods
- **Local sourcing** - to reduce environmental costs from transportation

4. Core Objectives of Green Marketing

- Minimize waste generation
- Reimagine and redesign product offerings
- Integrate environmental costs into pricing strategies
- Make eco-conscious practices economically viable
- Adopt innovative packaging and production techniques
- Promote sustainable business processes

5. Developing a Green Marketing Strategy

A robust green marketing strategy embeds sustainability into every stage of the marketing lifecycle from ideation and manufacturing to packaging, promotion and delivery. This tactic meets the moral demands of contemporary customers. Key elements include renewable resources, emission reductions and alignment with environmental causes. Companies that succeed in this area gain loyal customers, regulatory approval and a strong market position provided by they remain transparent and avoid misleading environmental claims (greenwashing).

6. The Eco-Conscious Marketing Mix (4P's)

Using an environmental perspective, green marketing integrates the traditional 4P approach.

- **Product**: Made to save resources and lessen the impact on the environment
- **Price**: Reflects the added value of environmental sustainability, with customers often willing to pay more for quality and eco-friendliness

- **Promotion**: Utilizes eco-centric messaging to promote green lifestyles and responsible brand images
- **Place**: Makes sure eco-friendly items are easily available to increase the number of potential customers.

7. Guiding Principles for Effective Green Marketing

To successfully connect with eco-conscious customers, marketers should follow these key rules:

1. **Know Your Audience** – Ensure that consumers are aware of and value sustainability issues
2. **Empower Buyers** – Let consumers feel that their choices make a real environmental difference
3. **Be Authentic** – Provide transparent and specific claims to build trust
4. **Maintain High Standards** – Eco-friendliness should never compromise product performance
5. **Value-Based Pricing** – Justify higher prices by communicating clear environmental and functional benefits

8. Emerging Opportunities in Green Marketing

- **Increased Consumer Awareness:** Today's customers actively seek out businesses that align with their beliefs.
- **Competitive advantage**: Sustainability initiatives build consumer loyalty and improve brand perception.
- **Global Expansion**: Eco-friendly goods attract customers from around the world and create new markets.
- **Cost Efficiency**: Long-term savings are frequently achieved by cutting waste and conserving resources.
- **Innovation Catalyst** – Green thinking encourages creative approaches to design, packaging, and operations

9. Challenges on Green Marketing Adoption

- High costs for sustainable raw materials
- Significant investment in eco-friendly technologies and Research and Development
- Lack of widespread consumer awareness
- Resistance to paying premium prices for green alternatives

10. Green Marketing Trends in India

Indian businesses increasingly view green marketing as a growth driver. Companies have recognized that consumers prefer health- and environment-conscious brands. Organizations incorporate corporate social responsibility values into their operations.

11. Future Directions and Industry Outlook

To prevent "green marketing myopia" overemphasizing environmental traits while ignoring customer value businesses must blend sound marketing principles with sustainability. Although traditionally viewed as a secondary topic, green marketing is gaining importance. Successful brands focus not only on eco-benefits but also on meeting real consumer needs with quality offerings.

Conclusion

Green marketing needs to strike a balance between corporate profitability and environmental responsibility. With increasing demand for sustainable products, companies must be ready to innovate and invest. By doing, foster long-term brand equity and customer trust in addition to helping to preserve the environment. As awareness continues to grow, green marketing will remain a cornerstone of future business success.

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IMPORTANCE OF LIQUID ORGANIC MANURES IN ORGANIC AND NATURAL 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 — primarily panchagavya, bio-digester, beejamrutha, jeevamrutha, vermiwash 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 liquid organic manures play crucial roles in maintaining soil health, enhancing crop productivity.

LIQUID ORGANIC MANURES:

These are becoming more and more important in organic farming these days. When liquid organic manures are applied topically, nutrients are absorbed twenty times more quickly than when they are applied topically. Liquid organic manures can be used to address short-term nutritional deficits. They enhance nutrient uptake and serve as a tonic or stimulant for crop development. In addition to enhancing soil quality, they are essential for increasing crop growth and yield. As a result, it has a huge function and promise in organic production systems. Organic

manures in liquid form Excreta from animal waste, such as urine, or extracts from the fermentation or decomposition of concentrated organic manures are examples of liquid organic manure. It can also be obtained from the partial or full composting, vermicomposting, or decomposition of organic matter.

Liquid organic manure is the extract obtained during the process of decomposition/fermentation of organic matter or during the process of partial or complete composting or vermicomposting or excreta of animals such as urine, or extracts obtained during the decomposition/ fermentation of concentrated organic manures.

Key Benefits:

- **Quick Nutrient Availability:** Liquid organic manures release nutrients rapidly, providing an immediate supply of nutrients to crops. This is particularly useful during critical growth stages.
- **Improved Soil Microbial Activity:** Liquid manures enhance the growth and diversity of beneficial soil microorganisms, which helps in the decomposition of organic matter and the cycling of nutrients.
- **Boosting Plant Health:** Some liquid organic manures, like fish emulsion or compost tea, contain growth-promoting substances and microorganisms that help plants resist diseases and pests.
- **Nutrient-Rich:** Liquid manures provide a balanced supply of nutrients, including macronutrients (nitrogen, phosphorus, and potassium) and micronutrients (iron, zinc, etc.), which are essential for healthy crop growth.
- **Cost-Effective:** They can often be made from farm waste (e.g., animal manure, plant residues, and food scraps), making them an inexpensive alternative to commercial fertilizers.
- **Sustainability:** Liquid organic manures reduce dependency on synthetic fertilizers, promote recycling of farm waste, and contribute to environmental sustainability by minimizing nutrient runoff.

1. Beejamrutha

Procedure for Preparation

Take 5 kg cow dung and tie it in a cloth. The cow dung is hanged in a bucket containing 50 1 of water over night



Next day morning the tied dung is frequently squeezed and dipped in the water.

- To this dung solution add 5 1 cow urine and 50 g calcium chloride solution prepared separately in 5 liter fo water.
- Dip the seeds / setts seedlings in this solution for 1 min and shade dried before sowing.

2. Jeevamrutha

Procedure for preparation

Jeevamruth liquid organic manure is used as a nutrient source. Jeevamruth is prepared by using 10- kg dung 10 lit cow urine, jiggery 2 kg, 2 kg pulse flour and 1 kg of garden soil mixed thoroughly in 200 1 of water taken in a drum or any container. The mixture is thoroughly stirred for a week twice daily and used. This is applied @ 500 1/ha to a soil before sowing and can also be applied as liquid manure to the soil along with irrigation water.

3. Panchagavya

Panchagavya is used as a traditional method to safeguard plant and soil microbes besides increase crop productivity. In Sanskrit, panchagavya means the blend of five products obtained from cow viz., cow dung,cow urine, cow milk, curd and ghee (clarified butter). When these ingredients are suitably mixed they have miraculous effects. However, to enhance the efficacy of Panchagavya, sugarcane juice, tender coconut water, ripe banana and toddy or grape juice are added depending on the availability of these materials.

Presence of growth regulatory substances such as IAA, GA3 and cytokinin, essential plant nutrients beneficial effective micro-organisms (EMO) predominantly lactic acid bacteria and certain fungi besides certain biofertilizers and plant protection substances can be detected in panchagavya. Panchagavya, single organic input, acts as a growth promoter and immunity booster.



Materials required:

i. Cow dung – 7.0 kg
ii. Cow urine – 3.0 litres
iii. Cow milk – 2 .0 litres
iv. Cow ghee – 1.0 kg
v. Curd made from cow's milk – 2 litres
vi. Sugarcane juice – 3.0 litres or Joggary-250 g
vii. Tender coconut water – 2.0 litres or Yeast-100 g
viii. Ripe banana – 12 numbers
ix. Toddy or grape juice – 2 litres
x. Mud pot (wide mouth)

Method of preparation:

Panchagavya is prepared by using 7 kg fresh cow dung and 1 kg ghee mixed thoroughly and kept for 2 days. It has to be thoroughly mixed daily thrice. After 2 days. And 3 liter cow urine + 10 liter water and is fermented for 15 days by stirring daily twice. Then add 2 liter of cow milk, 2 liter of curds, 3 liter of sugarcane juice or 250 a jaggary, 2 liter of coconut water, and 12 No's ripened banana and the mixture is allowed to ferment for 15 days. Stir the content daily a least 2-3 times. The solution is filtered and used as a spray at the rate of 3%

Recommended dosage

Spray system - 3% solution was found to be most effective compared to the higher and lower concentrations investigated. Three litres of Panchagavya to every 100 litres of water is ideal for all crops. The power sprayers of 10 litres capacity may need 300 ml/tank. When sprayed with power sprayer, sediments are to be filtered and when sprayed with hand operated sprayers, the nozzle with higher pore size has to be used.

Flow system - The solution of Panchagavya can be mixed with irrigation water at 50 litres per hectare either through drip irrigation or flow irrigation

Seed/seedling treatment - 3% solution of Panchagavya can be used to soak the seeds or dip the seedlings before planting. Soaking for 20 minutes is sufficient. Rhizomes of Turmeric, Ginger and sets of Sugarcane can be soaked for 30 minutes before planting.

Seed storage - 3% of Panchagavya solution can be used to dip the seeds before drying and storing them.

Periodicity of use:

1. Pre-flowering stage: Once in 15 days two sprays depending on the duration of the crop
2. Flowering and pod setting stage: Once in 10 days, two sprays
3. Fruit/pod maturation stage: Once during pod maturation

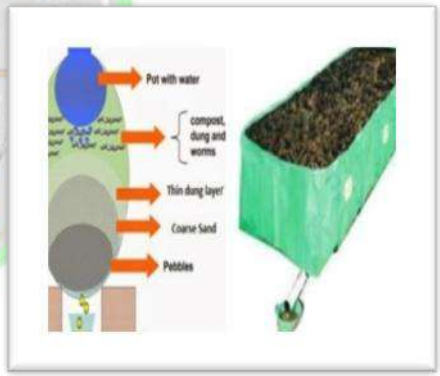
It has all essential nutrients and growth promoting substances. In addition to this, it improves the pest and disease resistance in crops.

4. Bio – digester solution



The bio-digester liquid can be used as a botanical pesticide and liquid manure. The bio digester of 16 feet length 10 feet width and 6 feet height is constructed and the dung, urine, organic wastes and botanical plants, mainly neem, calotropis, vitex, lantana, adothoda, ipomea, custard apple, agave etc., are added to the bio – digester and dairy unit washout let to the tank. The organic matter decomposes and digested liquid manure is ready in 3-4 weeks. It is regularly added to the soil along with water at the rate 200 liter per extracts and growth promoting substances which helps to manage pest and diseases and provide nutrients to the plants. Apart from adding to soil it can be also used as foliar spray at 5% solution.

5. Vermiwash



A liquid nutrient/ plant growth promoting substance obtained while vermiculturing/ vermin composting. It contains major nutrients, minor elements, PGR's, antibiotics, microflora and others. It is extracted at advanced stage of Vermicomposting by sprinkling water in vermitanks.

Method

i. A plastic barrel with 200 litres capacity is used for making vermiwash. The tap should be attached at bottom/lower side of the barrel to collect the vermiwash.

ii. A sand layer of 2 inches thick is placed at the bottom. Over this layer a 2 inchesthick small gravel layer is spread. On which two inch thick medium sized, and large sized gravel layers are placed respectively.

iii. Half feet thickness of one month old cow dung is spread over the gravel layer .Over this layer 2 feet thick slow degradable material (coconut fronts, pine needles) is spread.

Over this layer pre decomposed waste material is spread up to 80 % volume of the barrel.

iv. One inch thick soil layer is laid over the layer of waste material. The soil layer is covered with ½ feet thick layer of old cow dung.

v. Facilities should be created for the water to trickle down the barrel at the rate of 20-25 litres/day. Simple technologies like misters, pipe with tiny holes or even pot with hole etc. can be utilized.

Collection



i. The tap should be always kept open to collect the washings.

ii. The unit starts yielding good quality vermiwash after one week.

iii. The vermiwash is coppery brown in colour

iv. Vermiwash should be stored in cool dry place.

Uses

Root dip/stem dip

The seedlings before transplanting are dipped in vermiwash solution which is diluted 5 times with water for 15-20 minutes and then transplanted. Similarly the cuttings can also be dipped in the solution. 30

Foliar spray

Vermiwash is diluted in water 5 times and sprayed on the foliage of crops. It provides the plant with vital nutrients but also helps to control plant disease.

Soil drench

Vermiwash is diluted 10 times with water and the soil is drenched with the solution to prevent some of the soil borne pathogens

6. Cow Urine:

Cattle urine is a good plant growth promoter which farmers can use on all crops. This resource is hardly utilized by farmers and is wasted in most of the cases. Cattle urine has more than 24 different nutrients that are vital for plant growth.

Method

Cattle urine is diluted 10 times with water and used as a foliar spray. Care has to be taken that the concentrated cattle urine is not sprayed on the crop as it will result in scorching effect.

7. Matka Khad:

Ingredients:

Cow dung	:	5 kg
Cow urine	:	5 l
Jaggery	:	250 g

It was prepared by mixing 5 kg of cow dung, 5 litres of cow urine, 250 g jaggery and 2 litres of water thoroughly and put in an earthern pot of 20-25 litres capacity. The pot was filled up to 3/4 level for effective fermentation. Cover the earthern pot with a cotton cloth and buried in soil for 7-10 days with its neck outside soil. After 10 days, it was taken outside filtered well and used as a spray at the rate of 5 per cent at the tillering and panicle stage.

8. Enriched amrut ghol:

Ingredients:

Cow dung	:	1 kg
Cow urine	:	5 l
Decaying fruits (juice)	:	1 l

The above-mentioned ingredients are mixed thoroughly and let it ferment for 5 days. After that, it was filtered well and used as a spray at the rate of 3 per cent at the tillering and panicle stage.

9. Anda arkh:

Ingredients:

Lemon (juice)	:	25 No.
Egg	:	5 No.
Jaggery	:	250 g

These ingredients are mixed thoroughly and are closed for 10 days and can be used from the 11th day onwards. The solution is filtered well and used as a spray at the rate of 5 per cent at the tillering and panicle stage.

10. Amrit jal

Ingredients:

Cow dung	:	1 kg
Cow urine	:	1 l
Jaggery	:	50 g

The ingredients are mixed well in an earthern pot and then covered with a cotton cloth and tied. Allow 3 days to decompose, then it can be filtered and used as a spray at the rate of 3 per cent at the tillering and panicle stage.

11. Gokrupamrutha

Ingredients:	Mother culture	:	2 l
	Butter milk	:	4 l
	Jaggery	:	2 kg

Above mentioned ingredients along with 200 litres of water are thoroughly mixed in a drum and are closed for 5-7 days. Stirring should be done twice a day. This can be used as a spray at the rate of 5 per cent at the tillering and panicle stage.

Role in Organic and Natural Crop Production:

- **Soil Health and Sustainability:** Both green manuring and liquid organic manures 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:** These methods 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 and liquid organic manures lead to improved crop yields and better quality produce.

Conclusion

Liquid organic manures are 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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LABOUR ECONOMICS

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Abstract

Labour is typically the weakest partner but it may actually be the most significant and its function will be primarily dictated by how it responds to the other partner's job. Establishing more fulfilling living and working conditions for the men and women working in the sector encourages them to give their all for the advancement of the nation's welfare and increases their sense of involvement in the enterprise's goals. Effective and efficient manufacturing of goods and services has been appropriately considered one of the state's and industry's social obligations. For this reason, labour economics which studies the problems, solutions and changes of labour in the economy is essential.

Introduction

Labour economics is the study of labour marketplaces. Social policy concerns deal with the experiences of specific worker groups in the labor market or different facets of the employment relationship between workers and corporations.

The study of labor market dynamics and outcomes is known as labor economics. Its primary focus is on how employers and workers react to changes in pay, pricing, profits and working conditions. The study of the connection between wages and work opportunities is known as labor economics. This includes

- The relationship between income, wages and employment choice.
- How earnings, costs, and profits influence career decisions
- Rewards for and outcomes of training and education expenditures.

- How unions affect turnover, productivity, and wages.
- The impact of social policies on wages and employment, such as minimum wages, labor laws, and safety and health standards.

Employers, workers and the state's main partners face challenges as a result of economic development. Maintaining the pace of development should be the primary goal of all of them.

Definition of Labour

According to S.E. Thomas, "Labour connotes all human efforts of body or mind which are undertaken in expectation of reward".

Labour as a Production Factor, Labour is the term for human efforts made, either physically or mentally, with the intention of making money. Consequently, human mental or physical effort during the producing process is referred to as labour.

Wages, often known as employee pay, are the sums of money paid to workers in exchange for their productive labor. Labour is an active component of production and labor are also referred to as primary factors of production.

Definition of Labour Economics

Professor Phelps Brown says, "Labour economics is the study of organization, wage determination, employment level, social security, labour welfare, and labour relations". Labor economics takes a methodical and specialized approach to the study of labor dynamics.

Concept of Labour Economics

- Labor economics examines the providers of labor services (workers) and the demand for labor services (employers).
- Labor economics has both macro and micro dimensions. In macro, the issue centers on inflation and total unemployment. Micro, concentrates on the function of people and businesses in the labor market.
- Both mental and physical labor performed for financial gain is considered labor.
- The main input in the creation of products and services is labor, which also involves supply, demand, cost and utility.

Quantity and Quality of the Labour Force

Two factors determine the size of a nation's labor force relative to its total population:

1. The percentage of the population of working age
2. The percentage of those individuals who work for pay.

Rates of activity

The percentage of the whole population in a specific age and sex group for instance, women in their 30s to 34s who work for pay is known as the activity rate. Male activity rates are close to 100% between the ages of 25 and 50, but they start to decline beyond that when men start to retire.

Labor Quality

Health, physique and education and training all affect the quality of the labor force. There is proof that improvements in the 20th century's standard of living have significantly enhanced physical appearance. Improved health has increased productivity by lowering absenteeism and extending the working life, which benefits the economy by allowing workers to profit from their education and training. Training and education can be thought of as an investment, and it is possible to calculate the rate of return they provide.

Utilization of the Workforce

The shifts in the way labor is deployed in developing economies demonstrate how education and training contribute to economic development. In agriculture, a decreasing labor force has been able to produce more because to advancements in technology and expertise.

Setting Salary Rates

Collective bargaining between unions and management, individual bargaining between employees and employers or just custom can all be used to set wages. The existence of a separate agreement between the wage earner and the employer regarding the rate of pay was what set the wage earner status apart from other types of labor.

Bargaining Areas and Trade Unions

Maintaining a minimum wage for its members was one of the trade union's primary goals. The club could lower the likelihood of bidding against one another by enlisting everyone who worked in the same craft and district. It would also have a better chance of raising rates if it could restrict the number of people who could enter the trade by managing the number of apprentices. However, it had an interest in expanding its coverage to include all members of the trade throughout the labor market because it was still likely to face competition from members of the same craft moving in from other regions and some of its own members would relocate in pursuit of employment.

Salary Scale

The average salaries earned in various industries, vocations and geographical areas exhibit systematic disparities. The same methods for setting rates are used everywhere, the average wages that are found in different parts of a country exhibit a significant spread between the highest and the lowest. Differences in the localization of industry account for a large portion of the dispersion; for example, if the particularly high-paying iron and steel business is concentrated in one area, the average pay in that area will be boosted to that degree. However, there are geographical variations as well because similar work is often paid at various rates in different places.

Relevance and Extent of Labor Economics

The following factors make labor economics research significant.

Economists can better comprehend labor-related issues, such as those pertaining to fair wages or salaries, worker welfare, worker productivity, worker safety, gender-related issues, job security and job satisfaction.

Understanding the characteristics of the market where labor services are purchased and sold is made easier by studying labor economics.

Manpower planning, labor organization, labor relations, public policy, wage and employment theory, collective bargaining theory, social security, welfare and other topics are all covered in labor economics. The following fields of study fall under labor economics, per Dr. G.P. Sinha's writings:

- The size and makeup of the labor force and labor market, as well as the institutional structure of a specific economic system.
- The productivity, efficiency, working conditions, industrial relations and standard of living Workplace hazards and issues.
- Labor laws, labor welfare principles and practices, trade union management theory and practice, labor legislation, and job evaluation and personnel management principles.

Conclusion

Labour economics plays a critical role in shaping economies. It is not just about employment or wages, but about how society values and supports human effort. Through improved policies, education, welfare, and dialogue between employers, workers and

governments, labour economics aims to achieve fair, efficient, and sustainable labour market outcomes.

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PROSPECTS OF CROP IMPROVEMENT OF MILLETS

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Introduction

Millets are nutri cereals comprising of sorghum, pearl millet, finger millet (Major millets) foxtail, little, kodo, proso and barnyard millet (minor millets). These are one of the oldest foods known to humanity. These are one of the several species of coarse cereal grasses in the family poaceae, cultivated for their small edible seeds. Pseudo millets are so called because they are not part of the Poaceae botanical family, to which 'true' grains belong, however they are nutritionally similar and used in similar ways to 'true' grain (Tripathi *et al*., 2023). People are more concerned about sustainability and adequate nutrition these days in their mills, as a result, millets must be produced in order to meet the need of the food and nutritional security of growing population (Chapke *et al*., 2018).

Millets are high in nutrition and dietary fibre. They serve as good source of protein, micronutrients and phytochemicals and antioxidants. The millets contain 7-12% protein, 2-5% fat, 65-75% carbohydrates and 15-20% dietary fibre. The essential amino acid profile of the millet protein is better than various cereals such as maize, rice, wheat, and barley. Millets contain fewer cross-linked prolamins, which may be an additional factor contributing to higher digestibility of the millet proteins (Patra *et al*., 2023). In addition these nutri cereals are annual, short-duration (75 to 120 days) rainfed crops that grow well on shallow and low fertile soils with a pH range from acidic to alkaline soil. It has a low water requirement and can be grown even under extremely high temperatures and less rainfall. These are resistant to drought, resistant to

most diseases and pests, and need minimum care. Millets are nutri cereals and climate - resilient crops. (Malhotra, 2023)

CLASSIFICATION OF MILLET

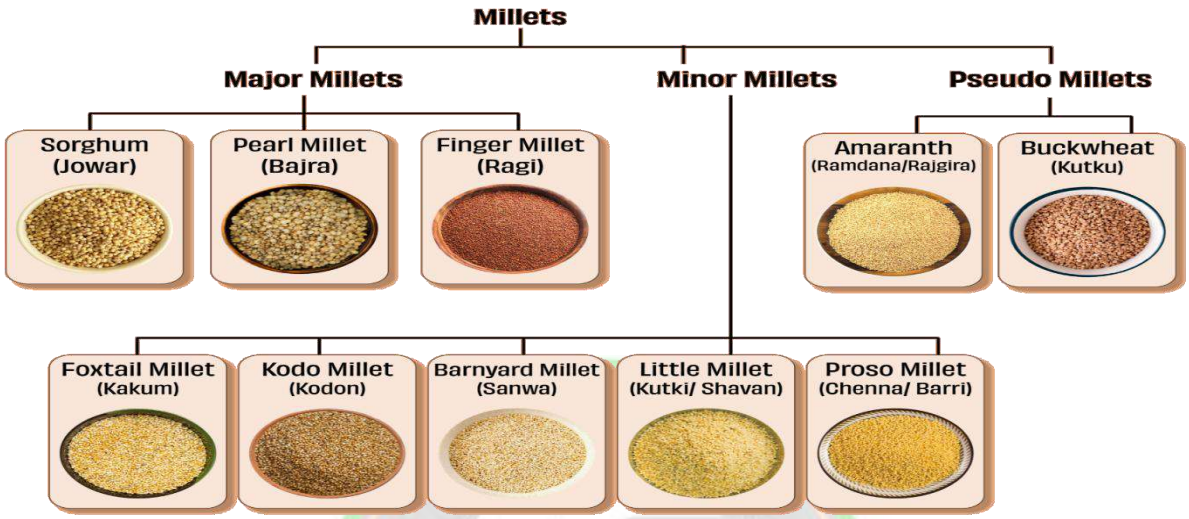
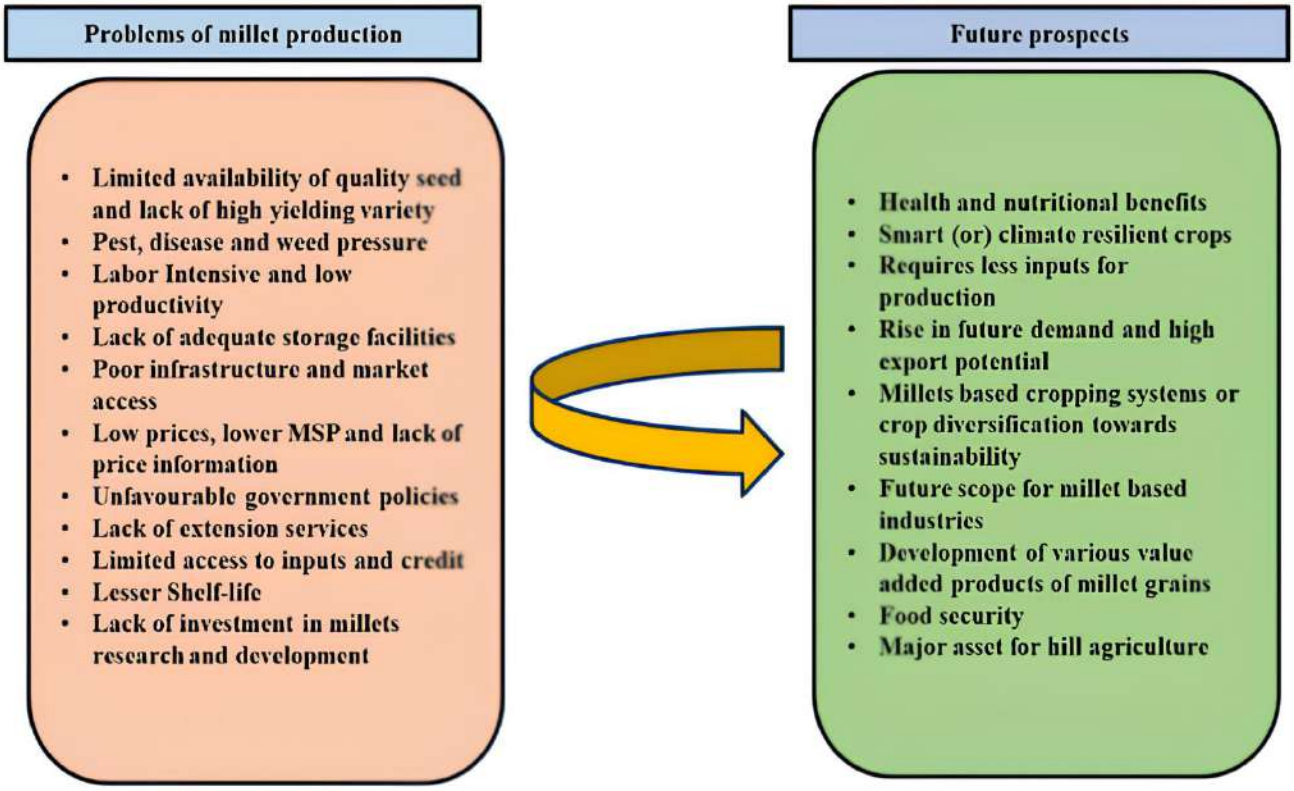


Fig 1: Classification of millets. [Source: Gopalan *et al.*, 2009]

CURRENT TRENDS IN MILLET PRODUCTION

Millets, being grown in more than 130 countries, have been considered an integral part of the diet of over half a billion people across Asia and Africa for centuries. Before Green Revolution, the millets are 40 percent of total grain production. Besides that the Green revolution had a negative impact on the production of millet. India produces 170 lakh tons of millet (20 % of the global output). The global average yield is 1,229 kg per hectare, while the average yield of millets in India is 1,239 kg per hectare. A profound change in the global food and agricultural system is needed to nourish today's 800 million people. It can be possible by focusing on millet production.

In India, Millets were among the first crops to be domesticated. In addition to many health benefits, millets are also good for the environment with low water and input requirement. In India, Jowar and Bajra are grown in most states like Maharashtra, Karnataka, Andhra Pradesh, Madhya Pradesh, Gujarat, Rajasthan, Uttar Pradesh, and Tamil Nadu, except North East states, Himachal Pradesh and Jammu and Kashmir. United Nations declared the Year 2023 as the **International Year of Millets** on 5th March 2021, on the proposal moved by India and supported by 72 countries.



USES OF DIFFERENT MILLETS

Ragi is an excellent source of calcium and is suitable for bone health, blood vessels, muscular contraction, and nerve function. Kodo millet is rich in iron. It purifies the blood, reduces hypertension, and regulates the body's immune system. Foxtail millet keeps neurons (brain cells) healthy. Little millet is good for the thyroid. Because of the goodness of nutrients, these are termed **Nutri Cereals.**

These should be part of the daily diet, and each millet should be consumed in a week on a rotational basis. Bajra is best to eat in winter and jowar in summer. Barnyard millet is usually eaten during religious fasts and is suitable for liver health. Browntop millet has anti-cancerous properties. Kutki, sama, and kagni can be substituted for rice.

WHY MILLETS DESERVE OUR ATTENTION ?

1. Millets are there when others are not
2. Millets can contribute to a healthy diet
3. Millets are climate-resilient
4. Millets offer promising livelihood opportunities for small scale farmers.
5. Millets trade can improve the diversity of the global food

6. Millets can be used in many innovative ways

PROSPECTS OF MILLET PRODUCTION

Prospects suggest potential future opportunities. According to farmers and extension agents, millets have significant potential because they require little to no input and can withstand biotic stress.

HEALTH BENEFITS

Millets are utilised by people with celiac disease since they are a gluten-free grain. The anti-diabetic feature of millet is its ability to lower blood glucose response and glycosylated haemoglobin, hence lowering the glycemic index and lowering the risk of developing diabetes mellitus. The phenolic chemicals included in millet grains eliminate free radicals, hence lowering oxidative stress (Lokesh *et al*., 2022). Similar to how millet extracts inhibit the proliferation of cancer cell lines, it possesses anti-cancer qualities. produce phase-2 detoxifying enzymes and prevent DNA damage. Reduced incidence of hypertension is achieved by millets' ability to stop low-density lipoproteins from oxidising.

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CHALLENGES IN USING NANO UREA

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Abstract

Nano urea has emerged as a promising innovation in sustainable agriculture, offering enhanced nutrient use efficiency, reduced environmental footprint, and improved crop yield. Despite its potential, several challenges hinder its widespread adoption. This article critically examines the key limitations and practical concerns associated with nano urea application in agricultural systems.

Introduction

Nano urea is a liquid fertilizer developed using nanotechnology that delivers nitrogen to plants more efficiently than conventional urea. It contains nitrogen particles at the nanoscale (typically <100 nm), which enhances leaf absorption and minimizes nitrogen losses through leaching, volatilization, and runoff. Developed as a sustainable alternative to traditional granular urea, nano urea aims to improve nitrogen use efficiency (NUE), reduce environmental impact, and lower the overall quantity of fertilizer needed.

Introduced commercially in India by the Indian Farmers Fertiliser Cooperative (IFFCO), nano urea is applied as a foliar spray and is claimed to replace a portion of conventional nitrogen fertilizers. While preliminary studies have demonstrated agronomic and environmental benefits, there are unresolved technical, regulatory, and socio-economic challenges that must be addressed.

Key Challenges

Inconsistent Field Performance

Although nano urea has shown promise in controlled experimental settings, its performance under diverse field conditions remains inconsistent. Variability in soil type, crop species, climatic conditions, and irrigation practices can significantly influence nano urea's efficacy. Unlike conventional urea, nano urea is typically applied as a foliar spray, and its effectiveness is influenced by factors such as crop species, phenological stage at application, and prevailing environmental conditions (Singh & Meena, 2023). When applied inappropriately or used as a complete replacement for basal nitrogen, it may result in nitrogen deficiency symptoms and yield penalties.

Limited Crop-Specific Research

Current scientific literature predominantly emphasizes the effects of nano urea on cereal crops such as rice and wheat. There is a dearth of comprehensive agronomic data on its application in horticultural, leguminous, and industrial crops. Furthermore, long-term studies assessing its impact on soil chemistry, microbial communities, and nutrient cycling remain insufficient (Kumar *et al*., 2024).

Dependence on Precise Application Techniques

As a foliar product, nano urea requires precise timing and uniform coverage for optimal uptake. Application inefficiencies due to lack of proper equipment (e.g., sprayers, drones) or user error may lead to suboptimal nitrogen absorption. This contrasts with conventional urea, which is broadcasted and less dependent on application timing or technique (IFFCO, 2022).

Knowledge Gaps and Farmer Awareness

A major barrier to widespread adoption is the lack of farmer awareness and technical know-how. Many smallholder and marginal farmers lack adequate training on dosage, frequency, and integration with other nutrient management practices. Inappropriate usage can negate its benefits and potentially damage crop health (FAO, 2021).

Storage and Stability Constraints

Nano urea, being a liquid formulation, has specific storage requirements. Its chemical stability may degrade under conditions of excessive heat, light, or prolonged storage. These limitations may pose logistical challenges, especially in rural or remote agricultural areas with limited infrastructure.

Regulatory and Safety Concerns

While nano urea is considered environmentally beneficial due to reduced nitrogen losses, concerns persist regarding the long-term ecological effects of nanoparticle accumulation in soil and water systems. Regulatory frameworks specific to nano-fertilizers are still evolving, and safety assessments related to human exposure and ecotoxicology remain limited (Meena *et al*., 2022).

Phytotoxicity & Health Risks

Some nanoparticles can penetrate plant tissues and induce oxidative stress. Moreover, workers handling nano-particles may face inhalation or dermal exposure risks (Buzea, 2008).

Market Misrepresentation and Product Quality

With increased interest in nano fertilizers, some commercial entities may make unverified claims about product efficacy. The absence of stringent quality control standards and certification mechanisms can lead to market infiltration by substandard or falsely labeled products, undermining farmer trust and scientific credibility.

Cost-Benefit Perception

Although nano urea is marketed as cost-effective—given its low application volume—farmers may perceive it as expensive or risky due to its unfamiliarity. Furthermore, without demonstrable yield advantages in every context, farmers may be reluctant to substitute conventional urea, which is often subsidized and widely available.

Conclusion

Nano urea represents a significant technological advancement with the potential to transform nitrogen management in agriculture. However, realizing its full benefits requires addressing multifaceted challenges related to application accuracy, scientific validation, farmer capacity building, and regulatory oversight. A cautious, evidence-driven approach, combined with robust field demonstrations and training programs, is necessary to foster sustainable adoption and ensure agronomic, environmental, and economic gains.

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RECENT ADVANCES IN ORGANIC PEST MANAGEMENT

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Abstract

Organic pest management has emerged as a pivotal discipline within sustainable agriculture, addressing the limitations of conventional chemical-based methods. This review explores innovative pest control approaches, including biological agents, pheromone-driven strategies, nanotechnological applications, and integrated pest management (IPM) frameworks. Emphasis is placed on their ecological benefits, species-specific precision, and capacity to reduce environmental burdens. While these techniques present promising alternatives, challenges related to regulation, public acceptance, and pest adaptability persist. The article advocates a holistic, multidisciplinary approach to pest control, with future prospects grounded in sustainability, collaboration, and technological advancement.

Introduction

Pest management is a vital component of agriculture, essential for protecting crop yields, public health, and ecosystem integrity. Traditional pesticide-reliant methods, while initially effective, have led to environmental degradation and rising pest resistance (Bogale et al., 2008). These issues have intensified the search for innovative, eco-conscious strategies. This review outlines advancements in organic pest control, including biological techniques, pheromone-based interventions, nanotechnology applications, and integrated pest management (IPM). It concludes

with a discussion of current challenges and future prospects, highlighting the need for holistic, sustainable solutions.

Biological Control

Biological control utilizes natural enemies such as predators, parasitoids, and microbial agents to suppress pest populations. These methods promote ecological balance and are increasingly deployed across varied agro-ecosystems. Examples include parasitic wasps for controlling aphids and Bacillus thuringiensis (Bt) for caterpillar management (Eeba et al., 2012).

Pheromone-Based Pest Control

Pheromone-based approaches manipulate insect behavior using chemical signals. These tactics—such as mating disruption and pheromone traps—target pests with precision, minimizing collateral damage to beneficial organisms and ecosystems (Grain South Africa, 2003). Applications include managing borers, moths, and grain pests with high specificity and reduced chemical use.

Nanotechnology in Pest Management

- Nanotechnology introduces novel capabilities for pest control, including:
- Nanoencapsulation for controlled release of pesticides
- Enhanced pesticide stability and uptake
- Smart formulations responsive to environmental triggers
- Though promising, nanotech in agriculture requires thorough safety evaluation and regulatory frameworks to ensure responsible use.

Challenges and Future Directions

- Despite significant potential, these strategies face various obstacles:
- Regulatory barriers that delay adoption
- Public concerns over safety and unfamiliar technologies
- Evolution of pest resistance to new control methods
- Progress demands multi-disciplinary research, stakeholder collaboration, and robust policy support to drive sustainable innovation.

Conclusion

Organic pest management is evolving with the convergence of biological control, pheromone strategies, nanotechnology, and IPM. Together, these approaches represent a paradigm shift away from reliance on synthetic chemicals. Continued research, public awareness,

and institutional backing will be crucial for establishing durable, eco-friendly pest control systems.

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BOOTSTRAPPING – AN INNOVATIVE FINANCIAL SOURCE FOR STARTUPS

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Introduction

Financing is a significant challenge for any startup. Entrepreneurs may possess great ideas, skilled teams and market acceptance for their products, but they may fail to raise the necessary funds despite having other resources in place.

Obtaining finances is no longer a significant challenge in this digital era, specifically because of the availability of innovative financial services. Numerous funding sources are accessible for startups. One such method of raising capital for startups is "Bootstrapping". Since a significant number of firms fail in their early stages owing to financial constraints, bootstrapping can be an ideal financing option for startups.

Bootstrapping

'Bootstrapping' refers to a business initiated by an entrepreneur without external financing. It involves launching a business from the ground up with minimal outside investment. This financial approach relies on the entrepreneur self-funding more than 75% of the business operations.

Bootstrapping fundamentally refers to launching a new business without relying on outside financial support. A bootstrapped startup depends entirely on its own generated revenue. Since many early-stage startups require limited capital, a typical bootstrapped business may utilize the entrepreneur's overdraft, credit cards, or personal savings. The business could be established while the founder continues to work part-time or takes on freelance jobs to pay the bills.

Possibilities for Bootstrapping

- Development of products
- Development of businesses
- Reducing the amount of money required
- Fulfilling the capital requirement

Techniques of Bootstrapping Finance

1. Including customer-related techniques,
2. Owner related financing and resources
3. Joint resource utilization with other endeavors
4. Payment delays
5. Stock investment minimization
6. Subsidy finance

Methods Pertaining to Customers

- Do business with clients who pay promptly
- Terminate business relationships with clients who often make late payments
- Offer cash discounts to clients for immediate payment
- Use interest on past-due payments from clients

Owner-Related Funding and Assets

- Paying the manager's salary later or later
- Using the manager's personal credit card for business purpose
- Borrowing loans or credit from friends or family
- Operating the entire company from home
- Enlisting the assistance of friends or family for business-related tasks, etc.

Collaborative use of resources with other enterprises includes

- Sharing fixed assets with other companies
- Sharing employees with other organizations
- Sharing business locations with others
- Renting equipment from other businesses for brief durations

Delaying Payments

- Wilfully failing to pay suppliers on time

- Preferring to lease rather than purchase equipment
- Deliberately postpone paying revenue taxes
- Buy second hand second-hand equipment instead of new equipments

Minimize Stock Investment Capital

- Accept the best terms from suppliers;
- Use economic ordering quantity to reduce stock investment capital;
- Coordinate purchases with other companies
- Prefer to purchase in consignment from suppliers
- Engage in bartering rather than buying and selling goods.

The Following are Examples of Subsidy Finance

- DIC & EDP Program subsidy,
- State Government Scheme subsidy,
- Central Government Scheme subsidy,
- Factoring business capital raise

Methods to Grow Bootstrap

Maintain financial discipline: Since bootstrap businesses never know when they will need money, it is crucial that they plan their expenses. As a result, they must exercise greater discipline while handling their starting capital

Objective profits: It is critical to put profit ahead of expansion. Since they can need funds at any time, bootstrap businesses should prioritize turning a profit as soon as possible. Prior to go into the more difficult areas with significant growth potential, they ought to attempt to conquer the easier-to-acquire markets.

Use second-hand equipment: Instead of buying brand-new office space or equipment right away. Try to concentrate on conserving money while pursuing your goals because you are still in the early stages and spending your own money.

Focus on cost effectiveness: Since the company is bootstrapped, it is critical that the entrepreneurs maintain appropriate cost control. It is their responsibility to determine how to reduce costs without compromising the quality of the goods or services they offer.

Develop as many skills as you can: Owners of bootstrapped enterprises should aim to learn as many skills as they can instead of outsourcing the work. The individual should be proficient in

all areas, including sales, accounting, marketing, and so forth. You will spend less money at the immediate star as a result.

Create an effective team: A bootstrapped business may not have a large workforce due to restricted finance, but it is essential that they have a small yet productive crew that can provide results.

Advantages of Bootstrapping

- Complete ownership retention
- Priority for customers
- Reduced financial obligations
- Improved handling of sluggish time,
- Control
- Freedom
- Time-saving procedure

Constraints of Bootstrapping

- Limiting a company's capacity for expansion
- Decreasing networking opportunities
- Raising personal risk
- Affecting the quality of products or services
- Limiting access to venture capitalists' help
- Lowering image
- Posing competition

Conclusion

Bootstrapping is one of the best ways for entrepreneurs to raise funds early on. This will help the new business owner gain control of their operation and avoid transferring ownership or stock to investors. There are various advantages, including as the entrepreneur's entire ownership and administration, the capacity to make quick decisions and effective cost control. Although it is extremely beneficial for entrepreneurs, bootstrapping a business is not an easy task; it necessitates meticulous strategic planning and smart budgeting. Despite the apparent rewards, it is quite challenging. An entrepreneur should be aware of both the benefits and drawbacks of their venture. Business success requires strategic thought for bootstrapping to be successful.

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OVERVIEW OF SEAGRASS

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Abstract

Seagrasses are submerged marine angiosperms vital for coastal ecosystems, supporting biodiversity, stabilizing sediments, and storing carbon. Globally, 72 species exist, with 15 found in India across key regions like the Gulf of Mannar, Palk Bay and Andaman Islands. Despite their ecological value, seagrass meadows are rapidly declining due to habitat destruction, pollution, and climate change. Conservation strategies include sustainable fisheries management, habitat protection, and restoration through replanting and reseeding. Recognizing their importance, the UN declared March 1 as World Seagrass Day, emphasizing the need for urgent global and local action to protect these critical habitats.

Keywords: Seagrass ecosystems, Coastal biodiversity, Habitat degradation and Conservation strategies

Introduction

Seagrasses are rhizomatous marine angiosperms, uniquely adapted to live and reproduce fully submerged in saline marine waters. They typically inhabit shallow, sheltered, soft-bottomed coastal habitats such as lagoons, estuaries, and backwaters. Globally, 72 species of monocotyledonous seagrasses have been identified (Green & Short, 2003). These ecosystems are considered the third most valuable ecosystem per hectare for the ecosystem services they provide, following estuaries and wetlands (Costanza et al., 2014; Mellors & McKenzie, 2008).

Seagrasses are remarkable for their ability to capture and store substantial amounts of atmospheric carbon dioxide (CO_2) via photosynthesis, storing it in both their biomass and sediments. Unlike terrestrial systems where carbon is mostly stored in plant biomass, over 90% of carbon in seagrass ecosystems is stored in sediments, often referred to as "blue carbon" (Fourqurean et al., 2012). Although seagrasses cover less than 0.2% of the ocean floor, they are estimated to sequester up to 18% of the total oceanic carbon stored in sediments (Duarte et al., 2013). Conserving healthy seagrass meadows is essential not only for biodiversity and fisheries but also for mitigating climate change by regulating atmospheric carbon.

Morphology

Seagrasses adapted to marine life after many physiological and morphological changes, including functional vascular systems, typical of many advanced terrestrial plant species, which have ribbon-like, grassy leaves (Hemminga and Durate, 2000). Morphologically the seagrasses size varies from a fingernail to plants with leaves as long as 1 meter. Shapes vary from oval, a fern, long spaghetti-like leaf, and a ribbon shape (Mellors and Mckenzie, 2008).



Fig. 1. Morphology of Seagrass

Criterias used to identify species level

- Leaf shape (ovoid, laminar, cylindrical)
- Cross-venation (present/absent)

- Leaf blade hairs (positive/negative)
- Rhizome type (monomorphic/dimorphic)
- Root hairs (sparse/inconspicuous or abundant/conspicuous)
- Leaf teeth (bidentate, tridentate, mid-vein split)
- Leaf scar type (open/closed)

Types of seagrass

- Star grass: elongated, elliptical blades.
- Eel grass: found in highly saline conditions on both coasts of the US.
- Manatee grass: cylindrical blades that is a food source for manatees.
- Shoal grass: flat blades that grows in shallow waters.
- Widgeon grass: branching stems and thin blades that grows in fresh and brackish waters.
- Turtle grass: wide, flat blades that is a habitat for turtles and other marine mammals.
- Paddle grass: paddle-shaped blades that grows in deep waters.
- Wild celery grass: ribbon-like blades that is also known as tape grass

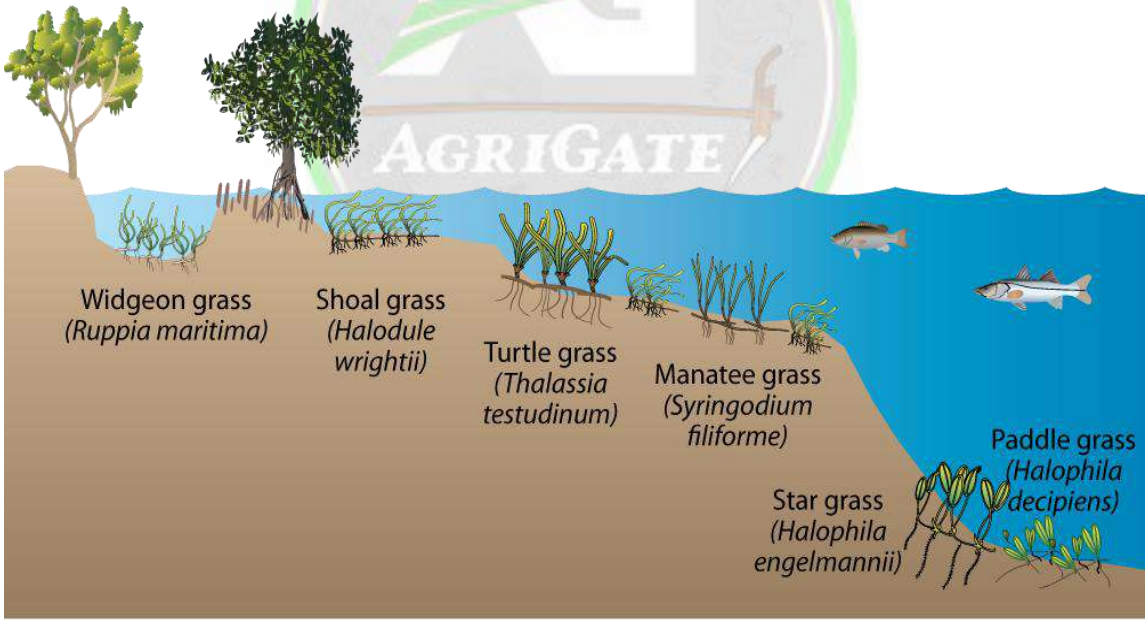


Fig. 2. Generalized distribution of seagrass species with depth

Seagrass in world

The seagrasses are estimated to have 72 named species globally, represented by 14 genera in six families (Hydrocharitaceae, Cymodoceaceae, Posidoniaceae, Zosteraceae, Ruppiaceae, and Potamogetonaceae), (Short et al., 2011). Seagrasses occur on various substrata,

generally in areas sheltered from wave action and strong currents. Seagrasses form extensive meadows from intertidal to a depth of 15 m dominantly, when the light intensity is maximum. In some areas, they can occur down to depths of 50–60 m (Coles et al., 2003). Seagrass productivities usually exhibit distinct seasonal variations, with rates increasing during spring and summer and decreasing during fall and winter (Lee et al., 2005).

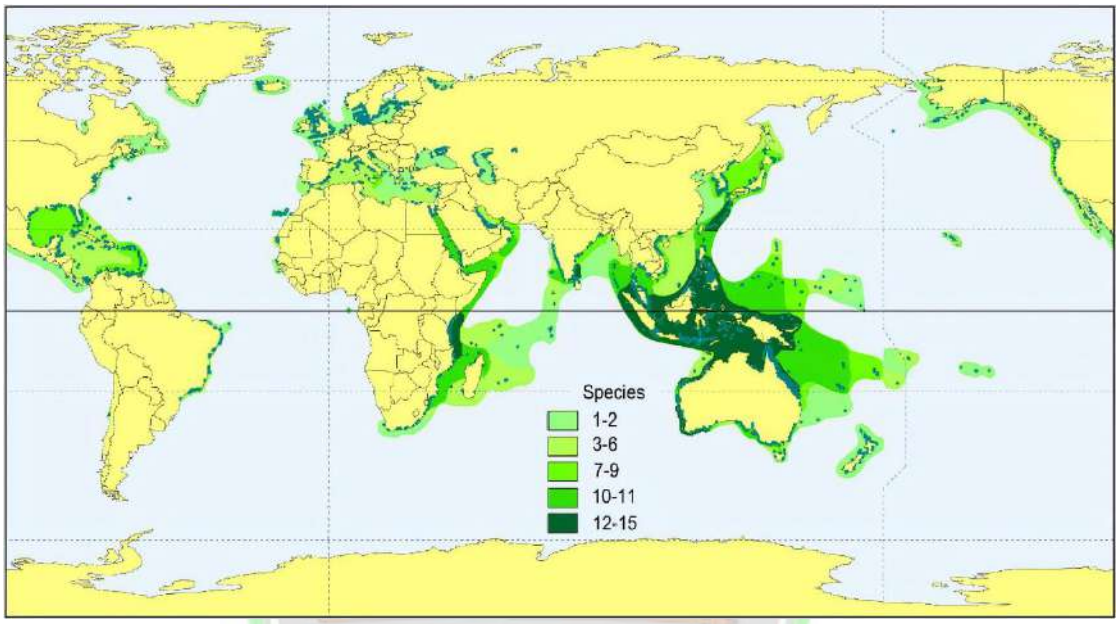


Fig. 3. Distribution of seagrass in world

Major seagrass habitats in India

Seagrass meadows commonly known as Prairies of the sea, serve as an important habitat for many vertebrates and invertebrates (Ramamurthy et al., 1992). Like other tropical countries, seagrass habitats in India are mainly restricted to the lower intertidal zone (mudflats and sandy regions) to a depth of 10-15 m (Jagtap, 1991). With 8000 km long coastline, India harbours seagrasses at isolated locations including bays, open seas, estuaries, lagoons and backwaters (Thangaradjou & Bhatt, 2018).

Seagrass in India

72 species in 6 families, and 14 genera reported worldwide. Among that, 15 species from 7 genera are reported in India. In India, dense seagrasses are reported with meager presence to more extensive meadows in all coastal States from Gujarat to West Bengal, and in the Island groups of Andaman & Nicobar and Lakshadweep, with records of species ranging from one to fifteen varying with locations.

The seagrasses in India are primarily located in the Palk Bay, Gulf of Mannar in the State of Tamil Nadu, Andaman and Nicobar Islands, Lakshadweep Islands, Chilika Lagoon (State of Odisha), Gulf of Kachchh (State of Gujarat) (Thangaradjou and Bhatt, 2018). Reports of *Ruppia maritima* from Chilika (Pattnaik et al., 2020) and the present study denote the occurrence of 15 species belongs to 7genera (*Enhalus, Halophila, Thalassia, Syringodium, Cymodocea, Halodule* and *Ruppia*) in the coastal waters of India.

Threats

Since the late 19th century, more than 20% of global seagrass meadows have been lost, with a current loss rate of approximately 1.5% per year (Waycott et al., 2009). Approximately 25% of seagrass species are now considered Threatened or Near Threatened by the IUCN (Short et al., 2011). Major threats include:

- Coastal development and infrastructure expansion
- Pollution from agricultural and urban runoff
- Destructive fishing practices (e.g., trawling, anchoring)
- Climate change, rising temperatures, sea level rise
- Invasive species and increased storm intensity

Activities like motor boating and bottom trawling increase turbidity, reducing light availability crucial for photosynthesis. Nutrient runoff can trigger algal blooms, leading to oxygen-depleted waters (hypoxia), which are lethal to seagrass (Orth et al., 2006; Unsworth et al., 2019).

Conservation Strategies

Seagrass ecosystems support numerous threatened marine species, including the dugong (*Dugong dugon*) and green turtle (*Chelonia mydas*). They provide nurseries for juvenile fish and crustaceans, supporting artisanal and commercial fisheries (Nordlund et al., 2016). Conservation efforts must include:

- Sustainable fisheries management near seagrass beds
- Protection of critical habitats through marine protected areas (MPAs)
- Restoration efforts including reseeding and transplantation (Van Katwijk et al., 2016)
- Reducing turbidity and nutrient input through better watershed management
- Community participation in monitoring and habitat stewardship
- World Seagrass Day, observed on March 1, aims to raise awareness globally (UNGA, 2022)

Currently, no specific international legal framework exists for seagrass protection; most conservation actions are driven by local and regional policies.

Restoration Techniques

1. Replanting Adult Shoots – harvesting healthy shoots from donor sites and transplanting them to restoration areas.
2. Reseeding – collection and redistribution of viable seeds from wild populations.

Both methods have shown success when properly implemented with site-specific environmental considerations (Orth et al., 2020).

Conclusion

Seagrasses are vital yet often overlooked marine ecosystems that offer immense ecological, economic, and climate benefits. They support marine biodiversity, sustain fisheries, stabilize coastlines, and play a significant role in carbon sequestration. Despite covering a small fraction of the ocean floor, their contributions to ecosystem services are disproportionately large. However, seagrass meadows are under serious threat from human activities, pollution, and climate change, leading to widespread degradation and loss. Protecting, restoring, and sustainably managing seagrass habitats is essential not only for marine life and coastal communities but also for global climate resilience. Strengthening conservation efforts, raising awareness, and promoting research and policy support are critical steps toward securing the future of these underwater ecosystems.

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USE OF BIO STIMULANTS FOR SUSTAINABLE FARMING

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Introduction

A class of agricultural inputs known as "bio stimulants" uses biological or natural processes to improve plant growth, development, and productivity. By promoting natural processes inside the plant and the surrounding soil environment, bio stimulants enhance plant vitality and stress resistance in contrast to fertilizers, which supply crucial nutrients like nitrogen, phosphorus and potassium. The importance of bio stimulants as instruments for sustainable agriculture is becoming more widely acknowledged. They support ecologically friendly farming methods by enhancing crop resilience and lowering the demand for synthetic inputs. They are also crucial in the context of climate change, helping plants adapt to uncertain weather and soil conditions

Definition and Scope

Bio stimulants are substances or microorganisms applied to plants or soils to improve physiological processes, regardless of their nutrient content. According to the European Bio stimulants Industry Council (EBIC), these products function by enhancing nutrient uptake, improving tolerance to abiotic stress, and increasing crop quality and yield.

Role in Sustainable Agriculture

- **Reduced Chemical Input:** Bio stimulants help minimize the use of synthetic fertilizers and pesticides, decreasing environmental pollution.
- **Improved Soil Health:** They enhance soil microbial diversity and structure, promoting long-term fertility.

- **Enhanced Stress Tolerance:** They help plants withstand drought, salinity, and temperature extremes, key in climate-resilient farming.
- **Higher Nutrient Use Efficiency:** By facilitating better nutrient uptake, they reduce nutrient losses and enhance productivity.
- **Support for Organic Farming:** Bio stimulants are compatible with organic agriculture standards.

Benefits of Bio stimulants

1. Improved Nutrient Uptake: Biostimulants aid in the more effective uptake of nutrients by plants from the soil, which benefits plant growth and development.
2. Increased Stress Tolerance: By making plants more resilient to environmental stresses like salt, drought, and extremely high or low temperatures, they enable crops to flourish under trying circumstances.
3. Better Soil Health: By encouraging healthy microbial activity in the soil, biostimulants improve nutrient cycling and soil health in general.
4. Improved Crop Quality: They can have a favorable impact on the flavor, color, nutritional value, and total yield of plants.
5. Less Need for Chemical Inputs: By reducing the need for artificial pesticides and fertilizers, biostimulants can support more environmentally friendly farming methods.
6. Enhanced Productivity: Biostimulants assist boost agricultural yields and enhance overall productivity by maximizing plant development and stress tolerance.
7. Encouraging Sustainable Agriculture: Biostimulants are eco-friendly and support sustainable farming methods, which is in line with the expanding demand for agricultural balance on both an ecological and financial level.

Types of Bio stimulants

1. **Humic and Fulvic Acids**
    - Improve soil structure and nutrient availability
    - Enhance microbial activity in the rhizosphere
2. **Seaweed and Algal Extracts**
    - Contain phytohormones like auxins and cytokinins
    - Stimulate root and shoot growth
3. **Protein Hydro lysates and Amino Acids**

- Aid in nitrogen assimilation
- Enhance photosynthesis and stress recovery

4. **Microbial Inoculants**
    - Include beneficial bacteria like Rhizobium, Azospirillum, and fungi like mycorrhizae
    - Improve nutrient solubilisation and plant resistance
5. **Chitosan and Other Biopolymers**
    - Act as natural elicitors of plant defence mechanisms
6. **Inorganic Compounds** (e.g., silicon)
    - Strengthen plant cell walls and increase resistance to biotic and abiotic stress

Differences Between Plant Biostimulants and Traditional Fertilizers

While both plant biostimulants and traditional fertilizers aim to improve plant growth, they function in distinct ways. Understanding the differences between them can help you decide when and how to use each for optimal crop health.

1. **Functionality:** The main nutrients that fertilizers provide are nitrogen, phosphorous, and potassium, which are necessary for plant growth. Their main function is to directly feed the plant by restoring the soil's nutritional levels. However, biostimulants do not supply nutrients directly. Rather, they improve a plant's capacity to absorb and utilize nutrients more effectively, triggering organic processes that support development, hardiness, and output.
2. **Plant Health:** Based on nutrients, fertilizers are designed to give plants the nourishment they require for fundamental growth. By emphasizing overall plant health, increasing stress tolerance, and strengthening the plant's reaction to environmental factors like drought or severe temperatures, biostimulants adopt a more comprehensive strategy.
3. **Effect on Soil Health:** Overuse of fertilizers, particularly synthetic ones, can damage soil microorganisms and result in nutrient imbalances, which can eventually cause soil degradation if not controlled. By enhancing the microbial habitat and promoting advantageous biological activity that sustains long-term soil fertility, biostimulants have a favorable impact on soil health.
4. **Regulation**: Fertilizers are strictly regulated based on their nutrient content and effects on the environment. Biostimulants are typically less regulated and fall into a separate

category. They are defined by their role in enhancing the plant's internal processes rather than acting as a direct source of nutrients.

5. **Environmental Impact**: Fertilizers can lead to runoff and pollution if over-applied, contributing to issues like eutrophication in water bodies.Biostimulants offer an environmentally friendly solution by *reducing the need for excessive fertilizer use and minimizing harmful environmental impacts.*

Conclusion

A promising area of agricultural innovation is represented by biostimulants. They offer a long-term solution to both boost crop productivity and safeguard the environment. The future of farming will probably be greatly influenced by biostimulants as environmental concerns and the world's food demand grow.



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GOAT HOUSING FOR MAXIMUM HEALTH AND PRODUCTIVITY

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Introduction

Domesticated goats are renowned for their versatility and capacity to provide meat, milk, and fiber, among other products. They are gregarious, intelligent creatures that live in both home and natural settings. They are renowned for their adaptability to a variety of environmental conditions. Housing tendency is a feature of all domestic animals. Goats are also no longer exempt from this propensity. Accommodations on a goat farm must be suitable and appropriate. Caretakers of goats may lose up to 50% of their young due to diseases and problems caused by dirty and poor housing. Sufficient shelter is essential for efficient reproduction, production, and reproduction. Goats usually need cover since they are afraid of the rain. In order to protect goats, especially young ones, from predators like dogs, wild animals, and thieves, shelter is also necessary. Water supply, ventilation, and clean air are important factors to take into account when selecting a goat farming location.

The adult goats are less productive and produce less when the weather is bad. The animal shed must be placed in an elevated position to allow for efficient drainage of the cleaned water, urine, and droppings. The farm should be situated outside of the city to prevent any public interference. However, it should be available for goods sales in the area. Enough land for growing grasses and feed crops, as well as pasture for grazing, are essential for successful farming. A consistent flow of electricity and water is another necessary condition for basic farm management. The choice of goat housing is influenced by the herd's size, the goat farming technique, and the resources available. Low-cost, locally available materials can be used to build

goat homes. Different groups of goats need different kinds of housing. These include sick goats, goatlings, breeding males, and pregnant does nearing the end of their pregnancy. Goat housing's primary features are its location, design, type of floor, and roof. The purpose and specific requirements dictate the form of the house, which can be either temporary or permanent, made of wood, bricks, or mud, and requires enough ventilation.

The floor needs to be easy to clean, and the wall and roof need to be strong. A well-drained elevated plain region is the ideal location for the animal housing. The direction should be east-west. To protect them from the heat, animals are linked north-south. Some people favor north-south shed orientation, which is inappropriate in arid climates. For adequate air circulation in the shed, few opt for the north-east or south-west directions. Proper light destroys the germs and keeps the shed dry. The shed will stay cool in the summer if the fodder trees are planted around it.

Advantages and Disadvantages of a Goat House the following:

- Urine, debris and manure can be dropped easily through the slatted floor and parasitic infestation is prevented.
- Suitable for large or small number of goats
- Reduced space requirements
- House is durable
- less labour to maintain and clean
- Remains relatively dry and clean
- Manure collection is easy and can be sold as fertilizer
- Stilts protect goats from large Predators
- No need of bedding



Overarching Considerations The area needs to be clean and dry. Because the collected droppings provide an ideal environment for the growth of disease-causing infectious agents and parasites, the goat home should be cleaned daily. Insufficient room for movement within the house limits the goats' activity, which in turn results in lower goat productivity. Even if they are written separately, goats enjoy seeing one another. Appropriate considerations must be made regarding

the kind of gates or dividers that are utilized. Breed-specific pen and door heights vary, with most breeds requiring a height of 1 to 1.25 meters. The shed should be painted before the monsoon season and lime washed before winter. The floor should have an even surface to absorb water content. Light and ventilation must be adequate. Pneumonia may result from a moist environment.

Goats are also more vulnerable to respiratory illnesses due to household congestion. The animals should be exposed to morning light and shed. It is recommended to replace deep litter every three months. While adult goats contract skin and foot illnesses from unclean homes, young goats are particularly vulnerable to parasites present in urine and feces. Sprays of fly repellent are to be used. For 10+1 Goats: To cut costs, a lean-to shelter can be built for 10+1 goats. 27 m2 of floor area is needed. Twelve children of various ages are anticipated if eight give birth to children with a 1.5 twinning rate. It can therefore accommodate ten girls, one boy, and twelve children. For 25+2 Goats: Two males are needed for every 25 females. However, it is preferable to preserve more males due to unanticipated factors like poor reproductive performance. Twenty of the 25 female goats will give birth to children under an organized agricultural system, where 80% of the females give birth annually.

Thirty children will be born annually if the twinning rate is 1.5. These children are raised for nine to twelve months. They will either be sold or retained as parent stock in the future. If they are sent to graze outside throughout the day, a paddock is not necessary. At night, they will be protected by the covered space.

Appropriate housing is crucial for goat farming operations to optimize health and output. The major principles and recommended processes for building and maintaining efficient goat housing systems are addressed in this chapter. It highlights crucial elements including temperature control, ventilation, space distribution, and protection from predators and bad weather. The chapter also discusses important components such as appropriate flooring, bedding materials, drainage systems, and feed and water stations to enhance comfort and hygiene. It is highlighted how improved reproductive performance, lower disease incidence, and higher overall production are all correlated with well-structured housing. In addition, creative housing ideas and practical guidance are offered, providing farmers with sustainable, reasonably priced solutions that are appropriate for various climatic and economic conditions.

Conclusion

The condition of their housing has a significant impact on the health, comfort, and productivity of goats. Farmers can enhance growth, reproduction, and milk production while reducing the risk of disease, stress, and injury by establishing a clean, spacious, and well-ventilated environment. Essential elements such as adequate drainage, appropriate bedding, adequate protection from extreme weather, and strong fence are necessary for a goat farming operation to be both profitable and long-lasting. Investing in high-quality housing is essential to modern goat farming since it maximizes farm profitability while also enhancing animal welfare.

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BLOCKCHAIN AGRICULTURE – REVOLUTIONARY APPROACH

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Abstract

Blockchain technology is increasingly recognized as a transformative tool in agriculture, enhancing transparency, efficiency and accountability across food supply chains. By decentralizing data storage, blockchain ensures secure, tamper-resistant records covering all stages of agricultural production and distribution. Its applications range from improving food safety and enabling timely farmer payments through smart contracts to promoting sustainable farming practices and reducing food waste. The high implementation costs, technological barriers and policy constraints, efforts like government subsidies, farmer training programs and user-friendly digital tools (e.g., QR codes and RFID tags) are driving its adoption. Established platforms like IBM Food Trust and Marco Polo Network demonstrate the potential of blockchain to create a more resilient and eco-friendly agricultural system. This paper investigates blockchain's role in fostering a transparent, efficient and sustainable future for agriculture.

Introduction

Modern agricultural systems rely heavily on Information and Communication Technology (ICT) for data management and operational oversight. The integration of blockchain introduces a decentralized framework, eliminating dependence on centralized authorities. In this system, every participant in the network has access to identical information, allowing for real-time verification of records. This approach strengthens data integrity and reduces the likelihood of tampering or corruption, making it a promising innovation for agricultural stakeholders.

Blockchain Applications in Agriculture

The use of blockchain in agriculture has gained momentum in recent years. A report by Insight Ace Analytic estimated the global blockchain market in agriculture and food supply chains to be worth USD 285.34 million in 2024, with projections suggesting a surge to USD 7.37 billion by 2031 at a compound annual growth rate (CAGR) of 43.76%. This rapid growth highlights the sector's increasing confidence in blockchain's potential to solve persistent challenges.

Key Benefits of Blockchain Adoption

- Enhanced Transparency and Traceability
- Improved Food Safety and Quality
- Streamlined Financial Transactions and Farmer Empowerment
- Support for Environmental Sustainability

Advantages of Blockchain in Agriculture

Transparency and Traceability

Blockchain provides an immutable, shared ledger where all stakeholders can record and verify critical information. This capability allows products to be tracked from farm to table, ensuring their origin, production methods and movement through the supply chain are fully visible. Such traceability is crucial for managing food recalls, addressing contamination issues, and enhancing consumer trust.

Enhanced Food Quality and Safety

Farmers can leverage IoT sensors to collect real-time data on soil moisture, temperature, and pH levels. This information, when stored securely on a blockchain, enables detailed monitoring of crop conditions and facilitates proactive measures to improve yield and quality. Over time, these insights support precision farming and reduce variability in harvests.

Promoting Sustainable Practices

Blockchain supports eco-friendly agriculture by enabling:

- **Reduced Food Waste:** Better inventory management minimizes spoilage.
- **Efficient Resource Management:** Monitors water, fertilizer and energy use.
- **Carbon Emission Tracking:** Logs greenhouse gas outputs for carbon credit systems.
- **Biodiversity Preservation:** Safely documents genetic data of crop varieties.

- **Incentives for Green Practices:** Smart contracts can reward farmers adopting sustainable methods.

Streamlining Payments and Market Access

By utilizing smart contracts, blockchain can automate financial transactions once predefined conditions are met, ensuring farmers receive timely payments. It also allows producers to interact directly with buyers, bypassing intermediaries and improving bargaining power.

Blockchain Benefit	Description
Transparent Transactions	Ensures full visibility of product and payment flows
Automated Smart Contracts	Releases payments based on delivery verification
Direct Market Access	Enables producers to negotiate directly with buyers
Reduced Operational Costs	Minimizes middleman fees
Global Trade Facilitation	Supports safe, traceable international transactions

Real-World Implementations

- **IBM Food Trust:** Connects farmers, processors, distributors, and retailers on a secure platform to enhance food traceability. For example, Pietro Coricelli tracked over 4 million kg of olive oil using this system, boosting consumer confidence in product authenticity.
- **Marco Polo Network:** Facilitates secure international trade by tracking shipments and automating payments based on delivery milestones.
- **Renault (Cross-sectoral Example):** Although in the automotive sector, Renault employs blockchain to streamline supply chain compliance and documentation, highlighting the technology's adaptability across industries.

Challenges and Proposed Solutions

Challenge	Proposed Solution
Limited Technology Access	Develop affordable, scalable solutions for smallholders.
Reluctance to Adopt	Conduct training programs and pilot projects.

Challenge	Proposed Solution
Regulatory Uncertainty	Collaborate with policymakers to create supportive laws.
Data Privacy Concerns	Establish clear data ownership and protection policies.
High Initial Costs	Offer subsidies, grants, and public-private partnerships.

Conclusion

Blockchain presents an opportunity to revolutionize agriculture by enhancing transparency, safeguarding data and enabling sustainable practices. While its implementation faces obstacles viz., cost, regulation, and technological gaps, targeted interventions including education, supportive policy frameworks and user-friendly applications can help realize its full potential. As stakeholders embrace blockchain, agriculture could evolve into a more equitable, efficient and environmentally responsible sector.

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GENOMICS OF PLANT PATHOGENS

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Abstract

The advent of genomics has transformed our understanding of plant pathogens, revealing the molecular mechanisms underlying host-pathogen interactions. Whole-genome sequencing, transcriptomics, and comparative genomics enable the identification of virulence factors, effector genes, and evolutionary trends in pathogenic microbes. These insights facilitate the development of precise diagnostics, resistance breeding, and novel disease management strategies. This article outlines the current status, tools, challenges, and future perspectives in the field of plant pathogen genomics.

Keywords : Pathogen genomics, effectors, virulence, genome sequencing, plant-microbe interaction, comparative genomics, bioinformatics

Introduction

Plant pathogens, including fungi, bacteria, viruses, and oomycetes, pose significant threats to global food security by causing substantial yield losses in crops. Traditional methods of pathogen identification and characterization were time-consuming and lacked precision. With the rise of next-generation sequencing (NGS) technologies, the genomics era has enabled rapid and comprehensive analysis of plant pathogens at the molecular level. Genomics provides a foundation for understanding pathogen biology, diversity, host specificity, and the evolutionary dynamics of virulence.

GENOME SEQUENCING OF PLANT PATHOGENS

1. First-Generation Sequencing to NGS

Earlier genome sequencing efforts using Sanger technology were limited to model pathogens. The introduction of NGS platforms (e.g., Illumina, PacBio, Oxford Nanopore) has made it feasible to sequence diverse pathogen genomes with high accuracy and at low cost.

2. Representative Genomes

Magnaporthe oryzae (rice blast fungus):

Revealed the presence of rapidly evolving effector gene families.

Phytophthora infestans (late blight of potato):

Showed extensive genome expansion with effector-rich regions.

Xanthomonas oryzae pv. oryzae (bacterial blight of rice):

Uncovered transcription activator-like (TAL) effectors.

EFFECTOR BIOLOGY AND GENOMIC PLASTICITY

Effectors are small secreted proteins produced by pathogens to manipulate host immunity.

Genomics has enabled:

- Identification of effector gene clusters.
- Prediction of effector functions using machine learning and homology-based tools.
- Insights into effector diversification via transposons, duplications, and horizontal gene transfer.

Pathogen genomes often show a **"two-speed genome"** architecture, where rapidly evolving, repeat-rich regions harbor effector genes, while core genomic regions are more conserved. This genomic plasticity facilitates rapid adaptation to host resistance.

COMPARATIVE GENOMICS AND PAN-GENOMICS

Comparative genomics among isolates of the same species or different species reveals conserved and variable gene content:

Core genome: Conserved across all strains; includes housekeeping and essential virulence genes.

Accessory genome: Varies across strains; enriched in effectors, resistance-breaking genes.

Pan-genome analysis helps in identifying population-level diversity and tracing pathogen evolution, migration, and host range expansion.

FUNCTIONAL GENOMICS AND TRANSCRIPTOMICS

Genomics is integrated with transcriptomic approaches (RNA-Seq) to understand:

- Gene expression during infection stages.

- Host-induced changes in pathogen transcriptomes.
- Regulation of effector gene expression under stress or plant defense responses.
- Gene knockout, CRISPR/Cas9 editing, and RNA interference (RNAi) further allow validation of gene function in pathogenicity.

APPLICATIONS IN DISEASE MANAGEMENT

Diagnostics: Genome-informed markers (e.g., qPCR, LAMP) improve pathogen detection and surveillance.

Resistance Breeding: Effector-informed resistance gene deployment helps in breeding durable resistant varieties.

Prediction Models: Genomics data feed into machine learning models to predict disease outbreaks and guide IPM strategies.

CHALLENGES AND FUTURE PROSPECTS

Complex pathogen genomes with repetitive elements and polyploidy complicate assembly and annotation.

Limited genomic data for many minor but emerging pathogens.

Need for better functional annotation tools and integration of multi-omics data.

Future trends include:

Long-read sequencing for complete genome assembly.

Real-time pathogen monitoring using portable sequencers.

Use of AI and big data analytics to interpret genomic data for actionable outcomes.

Conclusion

The genomics revolution has significantly advanced our understanding of plant pathogens, offering tools for precise diagnostics, functional studies, and resistance breeding. As sequencing technologies evolve and become more accessible, integrating genomics into plant pathology will be key to sustainable disease management and global food security.

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HARNESSING NUTRIGENOMICS FOR SUSTAINABLE AND PRECISION-BASED AQUA FEED DEVELOPMENT

Article ID: AG-V05-I07-139

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Abstract

The aquaculture sector must navigate the growing global demand for seafood while ensuring sustainable practices and addressing key challenges such as resource constraints, environmental concerns, and disease outbreaks. Conventional feeding methods often fall short in maximizing nutrient absorption, resulting in inefficiencies, excessive waste, and increased production costs. Nutrigenomics, which explores the relationship between nutrients and gene expression, presents a promising approach to enhancing fish health, growth, and feed utilization. Utilizing advanced genomic tools like reference genome sequencing and genome-wide polymorphic markers, researchers can pinpoint essential genetic traits linked to disease resistance, metabolic efficiency, and overall performance. Additionally, epigenetic mechanisms play a crucial role in modulating gene expression in response to environmental and dietary factors. Innovations such as gene editing and large-scale genomic research are transforming our understanding of genetic variations and their significance in aquaculture. Furthermore, integrating multi-omics approaches—including genetics, epigenetics, and gut microbiome analysis—provides deeper insights into how nutrition influences fish at the molecular level. Harnessing nutrigenomic advancements allows aquaculture to implement precision-based nutritional strategies, boosting productivity while promoting environmental sustainability.

Key words: Fish health, Feed efficiency, gene expression, multi-omics, nutritional strategies

Introduction:

The field of nutrigenomics in aquaculture has gained significant traction in recent years, driven by the growing need to enhance production efficiency and sustainability amid rising

global food demands. Foundational research by Abdelrahman et al. (2017) underscores the importance of developing genomic tools, such as reference genome sequences and genome-wide polymorphic markers, to better understand the genetic regulation of key traits in aquaculture species. Their study highlights the necessity of identifying and validating quantitative trait loci (QTL) across diverse strains and populations, which is crucial for genetic improvements in traits like disease resistance, feed conversion efficiency, and growth performance. Expanding on these findings, the authors discuss the use of genetic mapping and genome-wide association studies (GWAS) to identify genotypic variations associated with important phenotypic traits. Such insights are invaluable for selective breeding programs aimed at enhancing production traits, reinforcing the need for a comprehensive understanding of gene networks related to growth and reproduction.

In addition to genomics, epigenetics has emerged as a key area of study in aquaculture. (Gavery and Roberts, 2017) highlight how environmental factors influence gene expression through epigenetic mechanisms, shaping phenotypic responses in aquatic species. The application of advanced genomic technologies is further examined by Yáñez et al. (2022), who discuss their relevance in both aquaculture and livestock breeding. Their research emphasizes how tools such as gene editing and high-throughput genotyping enhance the understanding of genetic variability and the genetic architecture of critical traits.

In the context of disease management Sciuto et al. (2022) highlight the potential of genetic resistance traits in selective breeding programs to improve aquaculture efficiency and sustainability. While genomic advancements have enhanced selection methods, there remains significant potential for genetic improvement, especially in species with slower progress in breeding practices.

Houston et al. (2022) conclude by emphasizing the importance of expanding the use of genomic technologies in aquaculture. Although advanced genomic selection has significantly benefited species such as Atlantic salmon, many freshwater species continue to depend on conventional genetic methods. The emergence of genome editing offers promising opportunities to address sustainability challenges, highlighting the critical need for ongoing innovation in genetic research to enhance global food security.

Nutrigenomic Strategies for Optimizing Fish Diets

Dietary Manipulation

Modifying dietary formulations has been shown to greatly influence fish growth and overall health. Studies suggest that incorporating functional ingredients, such as nucleotides (NT) and nucleic acids (NA), into aqua feeds can enhance both growth performance and immune function. For example, in species like European sea bass, these bioactive compounds contribute to improved nutrient utilization, enhanced stress resilience, and a more robust immune response. By optimizing feed composition through nutrigenomic insights, aquaculture can achieve better growth efficiency while reducing the reliance on antibiotics and other chemical treatments (Pelusio et al., 2023). These components play a vital role in supporting metabolic pathways, particularly during periods of rapid growth when fish experience increased nutritional demands. By facilitating essential biochemical processes, nucleotides and nucleic acids contribute to enhanced protein synthesis, cellular repair, and immune system function. Their inclusion in aqua feeds ensures optimal energy utilization, helping fish maintain robust health and achieve maximum growth potential.

Enhancing Immune Function and Health through Nutrigenomics

The use of specific feed additives, such as sodium butyrate, has been investigated for its effectiveness in reducing the negative impacts of high plant-based ingredient inclusion in fish diets. Studies on gilthead sea bream have shown that this additive can counteract harmful alterations in the intestinal transcriptomic profile while also supporting immune function restoration (Estensoro et al., 2016). These findings underscore the potential of nutrigenomic approaches in strengthening disease resistance and promoting overall health in aquaculture species.

Molecular Mechanisms of Nutrigenomic Regulation

Nutrigenomics research has also aimed to uncover the molecular mechanisms by which dietary components influence physiological processes in fish. For instance, studies have identified the role of specific microRNAs (miRNAs) in regulating lipid metabolism, particularly in response to diets with different omega-3 and omega-6 fatty acid ratios. These miRNAs act as key regulators of gene expression, influencing fat deposition, energy utilization, and overall metabolic balance. Understanding these interactions can help optimize feed formulations to enhance fish health, growth performance, and resilience to metabolic disorders (Thoren, 2017).

Regulating these pathways is essential for formulating nutritionally balanced fish feeds that meet essential fatty acid requirements. By fine-tuning dietary compositions, nutrigenomic insights can help enhance lipid metabolism, improve energy utilization, and support overall fish health, ultimately leading to better growth performance and sustainability in aquaculture.

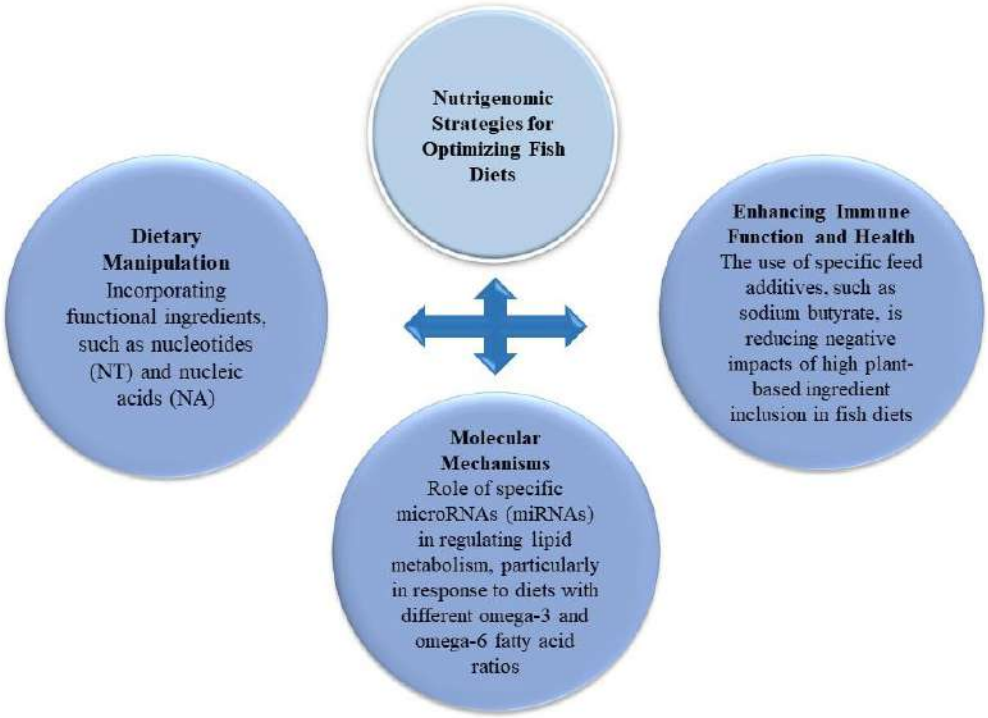


Fig 1. Pictorial representation of application of Nutrigenomic Strategies in Optimizing Fish Diets

Significance of Nutrigenomics in Aquaculture

Diet is a crucial environmental factor that plays a vital role in maintaining health and preventing diseases. From early neonatal stages, nutrition influences various physiological aspects, including energy supply, regulatory functions, and structural development, highlighting its significance in overall growth and well-being (Springmann and Gabbianelli, 2018). In recent years, omics approaches including genetics, epigenetics, and gut microbiome analyses have been integrated into nutrition research, offering a more comprehensive and advanced perspective on molecular nutrition. This regulation occurs either directly through nutrigenomics or via epigenetic remodelling, known as nutri-epigenomics (Bordoni, 2019). However, inter-individual differences, such as genetic variability, along with environmental factors including physical

activity, drug use, and exposure to food pesticide residues contribute to a wide range of complex and multifaceted effects on nutrition and overall health (Petracci, 2020).

A key objective of nutrition research is to regulate systemic chronic inflammation (SCI), which has detrimental effects on human health (Furman, 2019). Since SCI can elevate the risk of various diseases, including metabolic syndrome, cardiovascular disease, neurodegeneration, and cancer, a major focus of nutrigenomics is to identify foods and food-derived metabolites that regulate the expression of pro- and anti-inflammatory genes.

However, our understanding of the precise composition of the foods we consume daily remains incomplete (Barabási, 2020). Nutrigenomics explores how naturally occurring compounds in food influence the molecular expression of genetic information in an organism. Recent nutritional research has focused on understanding the impact of nutrients on gene expression and its regulatory mechanisms (Muller, 2003).

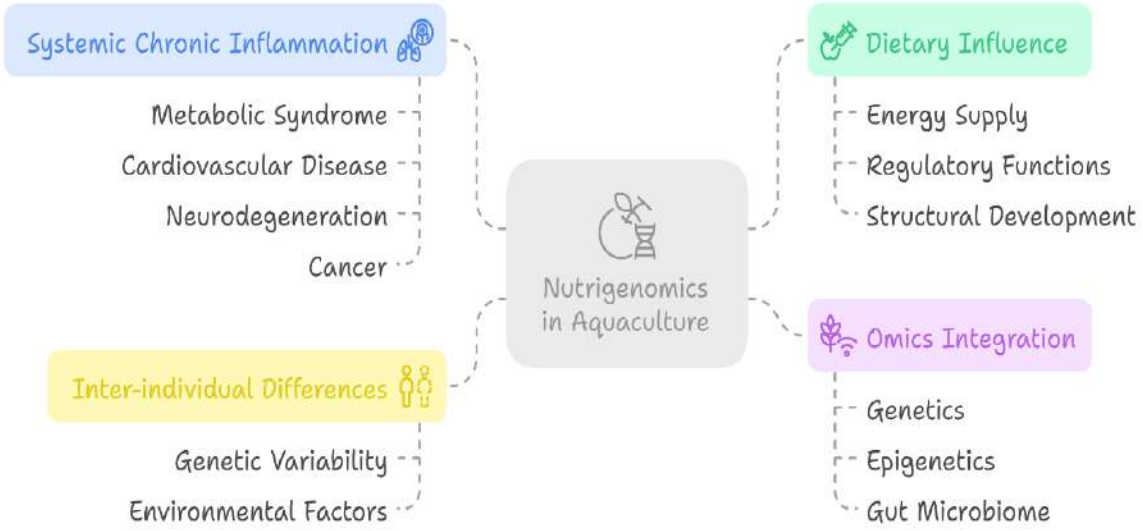


Fig 2. Pictorial representation of application of Nutrigenomic in aquaculture

Future Directions in Nutrigenomics

The application of nutrigenomic strategies in aquaculture holds the potential to revolutionize feed development by creating precision-designed diets tailored to the genetic makeup of specific fish species. This approach can enhance growth efficiency, optimize nutrient utilization, and promote sustainability. By deciphering the genetic mechanisms underlying metabolic responses and nutrient absorption, researchers can formulate feeds that not only

maximize growth but also strengthen immune function, improve overall fish welfare, and enhance resilience against diseases (Hakim et al., 2018)

Conclusion

Nutrigenomics has emerged as a ground breaking field in aquaculture, providing valuable insights into the intricate relationship between nutrition and gene expression. By utilizing advanced genomic tools, epigenetic studies, and multi-omics approaches, the aquaculture industry can develop targeted nutritional strategies that enhance fish health, growth rates, and feed efficiency. The incorporation of functional feed additives and strategic dietary modifications has already shown significant potential in strengthening immune function, regulating metabolism, and promoting sustainability. As research in this field progresses, nutrigenomics will play a pivotal role in refining aqua feed formulations, minimizing environmental impact, and ensuring the long-term sustainability of aquaculture. Looking ahead, integrating nutrigenomic findings with cutting-edge technologies such as genome editing and personalized nutrition will be crucial in tackling global food security challenges and fostering a more sustainable aquaculture industry.

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GIG ECONOMY

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Introduction

A gig economy is characterized by a market where a business, third party or online marketplace pays on a project basis or has a set-term contract. The gig economy's effects on the workplace are felt throughout industries. It has fundamentally altered the way we interact with people at work and has brought about a paradigm shift in how our economy functions. The number of gig workers will continue to increase as many of the best and brightest individuals turn to gig for their main source of income because of its unrivaled benefits. The numerous advantages the gig economy offers workers in terms of flexibility, employment, freedom, etc., it never had a detrimental effect on the industry work environment.

There has been a significant increase in the number of digital marketplaces that facilitate on-demand employment throughout a wider variety of industries and regions. The gig economy is a large and growing trend that is quickly changing the labor market in the economy.

Trends in Gig Economy

Gig economy trends discovered that the demand-supply of gig labor has become more worldwide distributed, in addition to the rise in popularity of gig job outsourcing platforms like freelancer. The majority of the demand originates in developed countries viz., United States, United Kingdom, Canada, Australia, etc. The low-income community provides the supply.

Market Size and Expansion: According to Startup Talky, The increasing use of contract and freelance work in a variety of sectors is driving this expansion. In India, the gig economy is

growing at a rapid pace, with estimates of 23.5 million gig workers by 2029-30, up from 7.7 million in 2020-21.

Digital Platforms and Technology:

The gig economy's expansion is mainly driven by mobile apps and digital platforms. These platforms make it easier for employees to communicate, streamline payment procedures and find job opportunities. AI and automation are also helping to streamline gig work, especially like matching workers with jobs and processing payments.

Remote Work and Flexible Arrangements:

The gig economy and remote work are inextricably linked. The gig economy is being used by a growing number of businesses to lower overhead expenses and gain access to talent from across the world. Gig employment provides flexibility and independence; it draws people who are looking for a good work-life balance.

Skills and Specialization:

The gig economy is becoming more and more reliant on niche talents. Freelancers with sought-after talents are thriving and making more money. In order for gig workers to stay competitive and adjust to changing employment market requirements, upskilling and reskilling programs are essential.

Protections for Workers and Benefits:

An increasing amount of attention is being paid to improving the social security and perks offered to gig workers. Programs like health insurance through government schemes and union budgets are being investigated. Prioritizing mental well-being and facilitating access to resources for gig workers are also becoming priorities.

Integration with Traditional Employment:

Traditional employment structures are becoming more and more integrated with the gig economy. Hybrid work models are developing that combine gig work with full-time jobs.

Specialty Gig Markets:

Online platforms are developing that are geared toward particular sectors and skill sets. The increasing demand for specialized solutions inside the gig economy is reflected in this trend.

Impact of Gig Economy

The expansion of the gig economy is being supported by the rise of technology, inexpensive labor and entrepreneurship. With the use of the platforms, employees may

communicate with one another regardless of location. The outcomes are improving productivity and optimizing the distribution of employment and income.

Specialization and Production

The rise in labor force participation rates and better access to lower-wage employees from other countries, the gig economy is to boost overall productivity by promoting greater work specialization and standardization.

Employment and Labor Participation

Labor force participation and employment labor participation in the gig economy originates from a variety of places. Lower-income folks are more likely than their higher-income peers to engage on labor platforms [Farrell, Greig, 2016]. There are no barriers based on caste, religion, gender, or geographical location.

Income Distribution

The advantages of the gig economy's emergence as a complicated and ambiguous phenomenon are not distributed equally. For less skilled workers in developed nations, working full time in the gig economy may result in lower income and greater economic insecurity [Bergman, Jean, 2016]. The wage rates of workers from less developed countries are likely to rise more quickly as they become more connected to potential employers in industrialized areas. A low-skilled employee from a wealthy nation will probably suffer when faced with international competition. As a result, the income distribution around the world is unbalanced.

Opportunities in Gig Economy

During the recession, when the majority of workers depended on short-term employment after losing their regular jobs, the word Gig Economy was created. The business world is seeing a growth in gig work prospects. The 'war for talent' is not a new phenomenon in the business sector, and due to intense competition, the majority of companies concentrate on their bottom lines in order to boost profits. Greater participation of gig workers in corporate activities can help businesses streamline their workforce and lower their operating expenses.

Constraints in Gig Economy

The daily rise in the number of gig workers, these gig professionals have struggled to consistently find high-quality employment and projects.

- There is a lack of regulation addressing gender disparities in acquiring gig labor on internet gig marketplaces (Barzilay & Ben-David 2016).

- The traditional job provides a framework and government help for creating a favorable atmosphere for high-quality work and projects, as well as worker protection and benefits (Donovan et al., 2016).

The major obstacle for the majority of freelancers (whether experienced or not) is landing regular employment on digital platforms. They struggle with safeguarding payments following the successful completion of their work. For human capital management, the gig economy has certain distinct difficulties.

Conclusion

The article examines the vital roles that stakeholders play in the gig economy and highlights the factors that affect the gig economy's growth and importance in India and globally. Gig culture can only be brought to emerging nations and remote areas of the world through digital platforms. Gig workers benefit from a variety of opportunities at the conclusion of the gig economy, the freedom to choose where they work, the ability to pursue their interests and access to job ads from all over the globe. However, freelancers face a number of challenges, such as reduced compensation, a lack of social perks and insecure employment.

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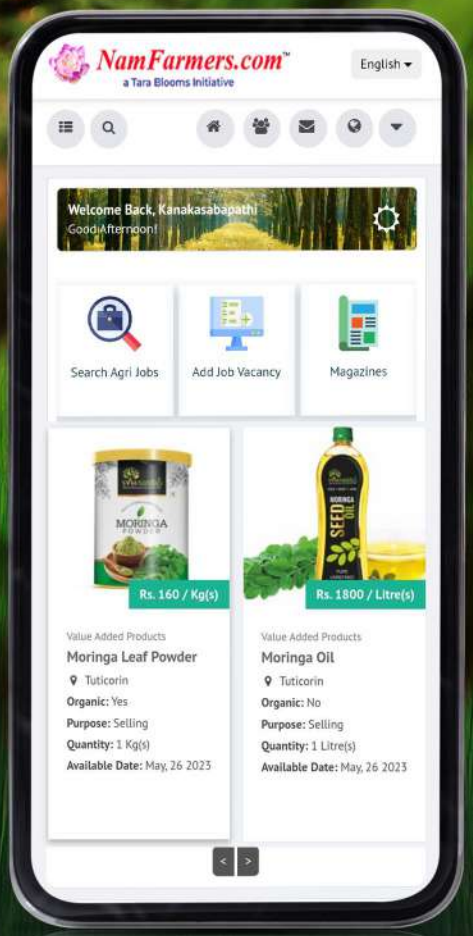
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