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AgriGate

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AgriGate

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. 06 – June 2025**” with immense pleasure. Our team is privileged to dedicate this issue to **farming community**. **World Milk Day** is observed globally on 1st June every year to celebrate the important contributions of the dairy sector to sustainability, economic development, livelihoods and nutrition. **World Environment Day** is observed every year on 5 June and is celebrated by more than 100 countries. The environment is a major issue, which not only affects the well-being of the people but also hampers economic development throughout the world.

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.

A handwritten signature in black ink, appearing to read 'R. Shiv Ramakrishnan'.

Dr R Shiv Ramakrishnan
Editor-in-chief
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REVOLUTIONISING AQUACULTURE VIA ARTIFICIAL INTELLIGENCE

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Introduction

Fisheries are essential for global food security, serving as a vital source of protein, employment, and economic stability. Aquaculture has become a major player in the global sea food industry. With the growing demand for seafood, fisheries production rose exponentially from 19 million tonnes in 1950 to nearly 223.2 million metric tonnes in 2022. India is the second-largest fish producer in the world, and its aquaculture sector plays a critical role in food security, employment, and foreign exchange earnings. India exported 1.73 million metric tonnes of seafood worth 63969 crores during 2022-23, with frozen shrimp contributing more than 75% to the export value.

Notwithstanding this growth, aquaculture is beset by several problems, such as labour-intensive culture methods, a lack of continuous observation, disease outbreaks, and poor environmental conditions. Conventional methods for monitoring growth and health often involve manual measurement, which is invasive, stressful to the animals, and inefficient. The adoption of modern technology in culture will enhance monitoring, enabling more efficient feeding and harvesting while maintaining environmental sustainability. Moreover, estimating the size and weight of fishes non-invasively is beneficial for both ecological and economic reasons. Biomass estimation, in particular, provides valuable insights into feeding patterns, potential health concerns, and production potential in aquaculture. Additionally, it can provide critical insights into the health of cultured species populations in at-risk situations, aiding in regulating and monitoring the farmed species. Optimising growth and yield in aquaculture can be improved

by employing modern tools of artificial intelligence like Internet of Things (IOT), computer vision, machine learning, and deep learning techniques.

Internet of Things (IoT) and Artificial Intelligence

The Internet of Things (IoT) is a system of interconnected computing devices, mechanical and digital machines, objects, animals, or people that are provided with separate identifiers and the ability to transfer data over a network without requiring a human-to-human or human-to-computer interaction. The IoT basically uses physical objects that are connected with sensors, software, and other technologies, and the exchange of data with other devices occurs through the internet. This system's function consists of data collection, image real-time acquisition, wireless transmission, intelligent processing, and information release.

Artificial Intelligence refers to the imitation of human intellectual processes by machines. AI is a broad-based field that has several subfields. Computer vision is an area of artificial intelligence (AI) that combines machine learning and neural networks to teach computers and systems to derive meaningful information from digital photos, videos and other visual inputs. Machine learning (ML) is a branch of computer science concerned with the automated recognition of patterns from data. ML algorithms build a model based on sample data (training data), in order to make predictions without being programmed to do so. Some of the Machine learning approaches include artificial neural networks, Bayesian models, Support vector machines, Decision trees, Instance-based models, and Deep learning. There are several applications of ML in aquaculture, such as the prediction of water quality & algal bloom, identification of infected fish. Thus, it will give farmers a better insight and improved decision-making. One popular Deep Learning model used here is YOLO (You Only Look Once), which is famous for its real-time object detection capabilities. YOLOv5 and YOLOv8 models have successfully been used in shrimp aquaculture for shrimp detection and tracking in underwater environments.

Applications of Artificial Intelligence in Fisheries

1. Detection and Tracking of Fishes and Shrimp

Artificial intelligence (AI) is employed in fisheries to automate the detection and tracking of aquatic species such as shrimp. A robust system combining YOLOv5 and YOLOv8 object detection models with Convolutional Neural Networks (CNNs) is used to accurately monitor shrimp in real-time, even under varying and challenging environmental conditions.

Specially designed near-infrared night vision cameras are used to capture images and videos, ensuring clear visibility in low-light or nighttime environments. These images are then labeled and processed with the help of CNNs, which are capable of learning complex features and patterns from diverse underwater scenarios.



Fig. 1 Detection of Shrimp

Through object detection techniques, particularly using bounding boxes, the system identifies shrimp in individual frames with an accuracy exceeding 80%. The YOLO models (You Only Look Once) allow the system to process images quickly and efficiently, making it ideal for real-time applications in aquaculture.

Once detected, the CNN model—trained on a wide range of environmental conditions—tracks the movement of each shrimp across frames. This enables continuous tracking of individual trajectories, supporting behavior analysis, activity monitoring, and biomass estimation.

By using AI in this manner, fisheries avoid the traditional, manual methods of tagging and counting, which are labor-intensive, invasive, and often disruptive to aquatic life. Instead, AI offers a non-invasive, automated, and scalable solution for shrimp monitoring, improving both accuracy and operational efficiency in aquaculture practices.

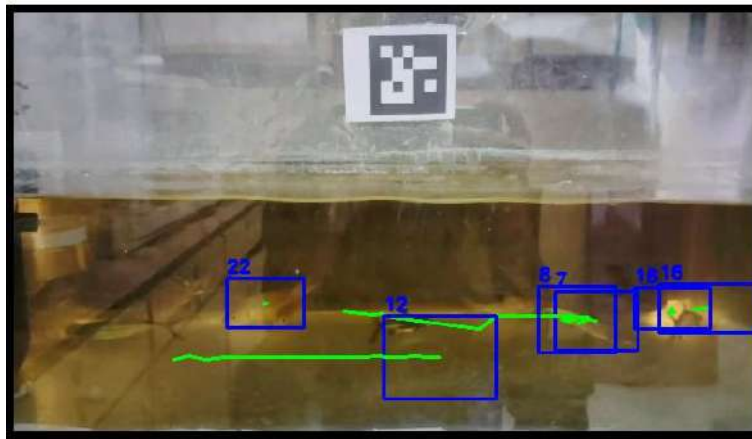


Fig.2 Tracking of Fishes

2. Behavioural Analysis

Behaviour analysis in fisheries is critical for monitoring fish health, detecting early signs of diseases, and maintaining animal welfare. It contributes to better feeding methods, less waste, and faster growth. Tracking mobility and activity promotes effective stock management and increases overall aquaculture productivity. Besides detection, the tracking information can be utilised to study behavioural patterns under various stress conditions, including changes in temperature, dissolved oxygen (DO), and pH levels. Behavioural abnormalities like gasping, abnormal swimming, and surface-seeking were noticed and categorised with ML models such as Naive Bayes and KNN. The varying behaviours in accordance with certain environmental cues can be used to detect abnormality. High temperatures, for instance, caused dying and surface-seeking behaviour, while low DO levels caused gasping and resting.

3. Biomass and Growth Estimation

Biomass and growth analysis in fisheries are critical for determining stock size, planning harvests, and maximizing production. They are useful for tracking fish growth rates, feed efficiency, and overall health. Accurate biomass estimation promotes sustainable resource utilisation and effective farm management. Shrimp biomass in culture ponds can be estimated non-invasively using computer vision and regression. The approach involved taking underwater

photos, then enhancing them with a fusion-based image restoration method

detecting using YOLOv8. ArUco markers served as reference scales for the accurate measurement of species length. These detectable markers under adverse conditions enabled the real-world translation of pixel-based measurements. After determining lengths, regression analyses such as Support Vector Regression (SVR), Exponential Regression (ER), and Random Forest Regression (RFR) approximated the weight of shrimp. This method is efficient in turbid water conditions with low visibility. By relying on only a few characteristics—DOC and length—the system has achieved high efficacy and applicability in the real world.

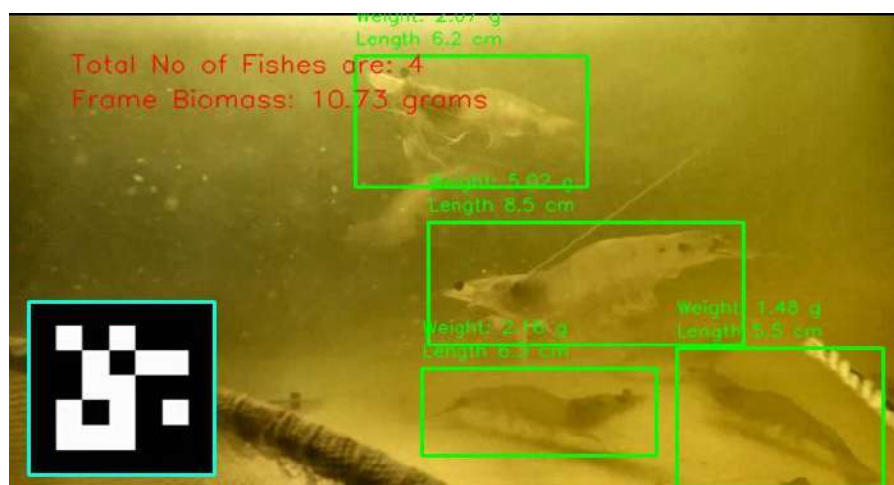


Fig.3 Growth and Biomass Estimation

Conclusion

Underwater machine vision, powered by AI and deep learning, holds immense potential to transform shrimp aquaculture by enabling non-invasive monitoring, accurate biomass estimation, and detailed behaviour analysis. Despite current challenges such as high equipment costs, technical expertise requirements, and complex underwater conditions like turbidity and light distortion, ongoing research continues to address these limitations. As technological advancements progress, these intelligent systems will become more accessible and practical for everyday use in aquaculture. Ultimately, AI is poised to drive the future of smart aquaculture, enhancing productivity, boosting profitability, and promoting environmentally sustainable farming practices through data-driven decision-making.

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ARTIFICIAL INTELLIGENCE IN CONTAMINATED SITE REMEDICATION

Article ID: AG-VO5-I06-02**S.Shenbagavalli* and A.Lakshmipriya**

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Introduction

The integration of Artificial Intelligence (AI), particularly through Machine Learning (ML) and Deep Learning (DL), has become increasingly significant in the field of environmental science over the past decade. AI technologies are particularly impactful in the remediation of contaminated sites, enhancing the efficiency and effectiveness of various processes.

Advantages of AI Tools

AI significantly improves data processing capabilities, allowing for quicker and more sophisticated analysis of environmental data. This results in refined remediation strategies that can more effectively address contamination issues. Furthermore, AI reduces reliance on traditional extensive sampling methods, which can be costly and time-consuming. By utilizing AI, practitioners can streamline their efforts, ultimately leading to improved environmental management (Hanna & Lopes, 2020).

Challenges in Remediation:

Contaminated sites pose serious health and environmental risks, necessitating thorough site characterization and careful management. These processes generate vast amounts of data, which are often underutilized. Additionally, the complexities of remediation are exacerbated by high financial costs and the inherent uncertainties associated with contaminant behavior and environmental conditions. This suggests that traditional approaches can be inefficient and may not fully utilize the potential of available data. Huang and Chen (2018)



FIG.1. Site characterization thorough AI

Data Analysis: AI tools provide deeper insights into contamination patterns and sources, enabling researchers and practitioners to make informed decisions based on comprehensive data insights.



FIG.2. Data analysis through AI

Site Characterization: Machine learning techniques assist in predicting the spatial distribution of contaminants by interpreting various data inputs, such as soil and groundwater samples, leading to improved site assessments and management. ((Zhou & Li, 2021).

Risk Assessment AI enhances the ability to identify risk hotspots, allowing for more focused remediation strategies that target specific areas of concern, thereby optimizing resource allocation.

Remediation Technology Selection:

AI leverages extensive historical data on contaminants and corresponding remediation methods to guide the selection of the most suitable strategies tailored to the specific conditions of each site. By analyzing past performances and outcomes, AI can suggest effective approaches that enhance overall remediation success.

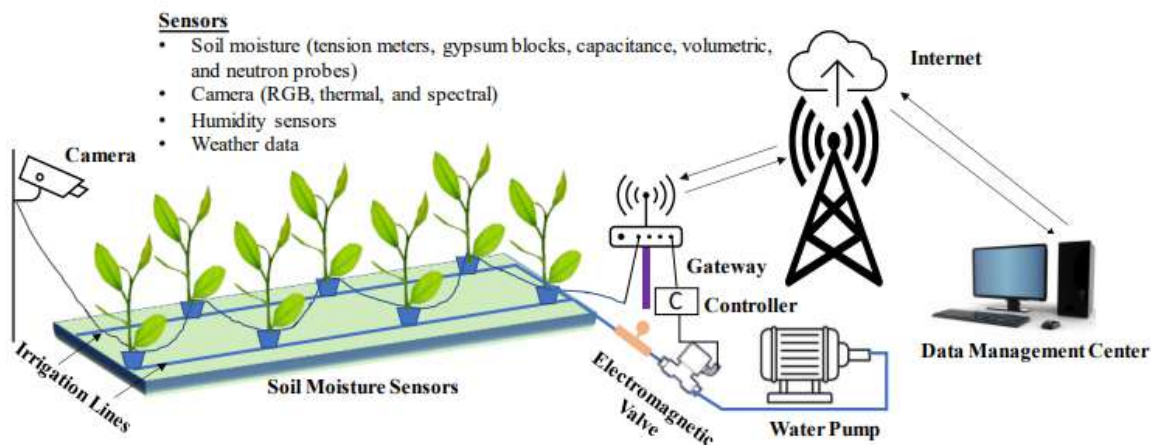
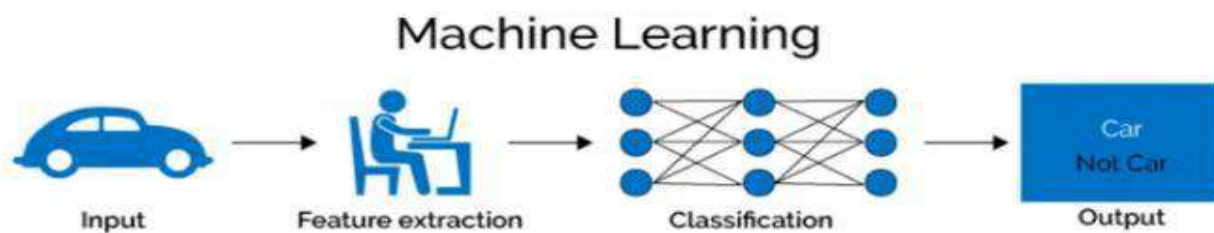


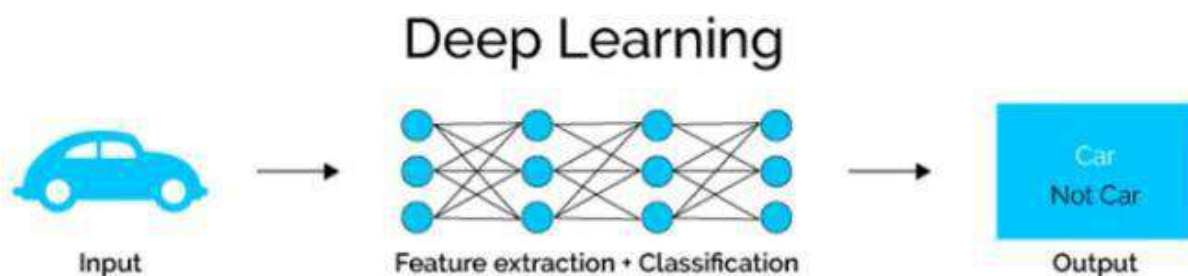
FIG.3. overall approaches for effective remediation through AI

Emerging AI Technologies

Machine Learning: Encompasses various approaches, including supervised, unsupervised, and semi-supervised models, that facilitate the prediction of contaminant behavior and the optimization of remediation methods. (Cong et al., 2019)



Deep Learning Utilizing neural networks, deep learning improves the precision of contaminant detection and data analysis by effectively managing and interpreting complex datasets. This leads to better-informed decisions in remediation practices. (Gupta & Natu, 2021).



Conclusion and Future Directions

AI-based decision-support tools present transformative opportunities for the field of contaminated site remediation, promoting more data-driven and efficient approaches. Future research should concentrate on refining AI applications to enhance their capabilities in addressing increasingly complex environmental challenges effectively. This ongoing improvement in AI has the potential to significantly advance environmental protection and public health outcomes. This summary emphasizes the critical role that AI plays in improving remediation practices and highlights its potential to enhance efficiency and effectiveness in addressing environmental contamination. By leveraging advancements in AI, practitioners and researchers can greatly improve environmental outcomes for affected communities.

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REVOLUTIONIZING SMALL-SCALE INLAND FISHERIES WITH ADVANCED REMOTE SENSING

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Abstract

Inland small-scale fisheries provide over 40% of global finfish production yet occupy less than 0.01% of global water, making them essential but often overlooked due to sparse data and limited monitoring. Traditional methods are costly and inefficient, contributing to the underreported “hidden harvest.” These fisheries face mounting threats from pollution, habitat loss, and climate change. Remote sensing technologies, using satellites, drones, and Artificial Intelligence(AI), offer a game-changing solution by enabling real-time, large-scale monitoring of water quality, habitats, fish stocks, and illegal fishing. Tools like hyperspectral imaging, LiDAR, and SAR, combined with AI, enhance precision and predictive analysis. While data complexity remains a challenge, rapid advances in sensors and machine learning are improving accessibility. Integrating remote sensing with ground-truthing and GIS empowers informed decision-making, bridging critical data gaps and supporting sustainable management. These “eyes in the sky” offer a vital path toward resilience, conservation, and food security for communities reliant on inland fisheries.

Keywords: GIS, Satellite monitoring, Water quality assessment, Habitat mapping, Sustainable management

Introduction

Inland fisheries, often operating on a small scale across countless lakes, rivers, and ponds, play an undeniably critical role in global food security and local economies. These operations contribute over 40% of the world's reported finfish production, a remarkable feat considering they utilize less than 0.01% of the total global water volume. For millions

worldwide, particularly in developing regions, these fisheries are vital sources of food and livelihoods.

Despite their immense importance, this sector faces unique and formidable challenges. Inland fisheries are inherently diverse, highly dispersed, and often operate with limited resources or expertise for monitoring and management. Their small scale and fragmented nature mean that traditional data collection methods are frequently costly, labor-intensive, or geographically constrained, leading to a significant lack of comprehensive information. This pervasive data scarcity often means the true economic and social contributions of these fisheries remain unrecorded or drastically underreported, a phenomenon sometimes referred to as the “hidden harvest”. This lack of visibility can, in turn, hinder effective policy formulation and resource allocation, as their vital role for local communities is not fully recognized.

Furthermore, inland aquatic ecosystems are acutely vulnerable to a range of environmental changes, including pollution, habitat degradation, and the accelerating impacts of climate change (Saxena, 2025). Traditional stock assessment methods, often developed for large-scale marine fisheries, may not be suitable for the complex and diverse conditions found in inland freshwaters. This creates a pressing need for innovative solutions that can provide the necessary data for sustainable management.

This is where advanced remote sensing emerges as a game-changer. Remote sensing, defined as the science of acquiring information about objects or phenomena from a distance without direct physical contact, offers a powerful and non-invasive approach to overcome these limitations. By providing comprehensive, real-time data over extensive geographic areas, remote sensing delivers unprecedented insights for sustainable management and conservation that would otherwise be impossible to obtain with conventional methods. The ability of remote sensing to systematically collect broad-scale data directly addresses the fundamental challenge of data scarcity, moving beyond localized sampling to provide spatiotemporally complete coverage. This capability is particularly crucial for bridging the development gap, as the transfer of cost-effective remote sensing technologies can empower developing nations to manage their inland fisheries sustainably, contributing to global food security and local livelihoods.

The Science of Remote Sensing unveiling the water bodies

At its core, aquatic remote sensing is about understanding how light interacts with water. Just as a glass of muddy water looks different from clear water, the color and clarity of a water

body are determined by what is suspended or dissolved within it, be it inorganic sediments, microscopic plankton, larger seaweed, or dissolved organic matter. Remote sensing translates these observable “optical properties” into valuable information about the water's composition. Each of these components absorbs and scatters light differently across the electromagnetic spectrum, creating unique “color signatures” or “spectra” that specialized sensors can quantify. For example, clear, deep water typically appears blue to our eyes, while muddy water looks brown, and water rich in algae can appear greener.

Remote sensing instruments measure the light energy radiating from water bodies, specifically focusing on the “remote sensing reflectance” (R_{rs}). This R_{rs} is essentially the ratio of light scattered backward from the water to the total absorption and backscattering within the water column. Scientists then use this R_{rs} quantity in complex algorithms to compute valuable data products, such as chlorophyll concentration. A significant challenge in aquatic remote sensing is that water is inherently a “dark target” compared to land, meaning it reflects very little light. Therefore, instruments must be exceptionally sensitive and precisely calibrated in the visible light range to accurately detect subtle changes in water composition.

Data for aquatic remote sensing can be collected from a variety of platforms, each offering distinct advantages based on the scale and frequency of monitoring required:

- **Satellites (Space-borne):** These platforms provide extensive and periodic scanning of Earth's surface, with revisit times ranging from daily to monthly, offering unparalleled “synoptic coverage” over vast areas. This broad view is crucial for capturing large-scale patterns and dynamic phenomena across entire regions. Key satellite missions include Landsat, MODIS, Sentinel-2, Sentinel-3, and the new NASA PACE mission, which promises global hyperspectral observations for water quality monitoring.
- **Aircraft (Airborne):** Operating at lower altitudes, aircraft-mounted sensors can provide data with higher spatial resolution and are often deployed for targeted surveys over specific areas.
- **Drones (Unmanned Aerial Vehicles - UAVs):** Drones offer exceptional flexibility, cost-effectiveness, and precision for data collection, particularly in smaller, often inaccessible inland areas. They can carry various sensors and integrate with artificial intelligence for real-time analysis.

- **Ships and In-situ Observations:** While remote sensing gathers data from a distance, direct, on-the-ground (or in-water) measurements from ships or autonomous surface/underwater vehicles are indispensable. This “ground truthing” is crucial for calibrating remote sensing models and validating their accuracy against real-world conditions.

When selecting remote sensing data for a specific application, it considers four critical types of resolution:

- **Spatial Resolution:** This refers to the size of each pixel in the imagery. For smaller inland water bodies like lakes and rivers, a higher spatial resolution is essential to discern fine-scale features and avoid averaging out important details.
- **Temporal Resolution:** This indicates how often imagery is captured for a given area. Frequent overpasses are necessary to capture dynamic natural phenomena and track rapid changes over time, such as algal blooms or sediment plumes.
- **Spectral Resolution:** This describes the number and narrowness of the “colors” or bands of light a sensor measures. Hyperspectral sensors, with bandwidths less than 10 nm, provide significantly more detailed information than multispectral sensors by capturing continuous spectral data, offering a more precise “fingerprint” of water constituents.
- **Radiometric Resolution:** These measures a sensor's sensitivity to subtle changes in brightness, impacting its ability to detect minute variations in light intensity reflected from the water.

Precision Management: Mapping Habitats and Monitoring Water Quality

Advanced remote sensing, often seamlessly integrated with Geographic Information Systems (GIS), has become an indispensable tool for mapping critical fish habitats and identifying “Potential Fishing Zones” (PFZs) (Ya’acob et al., 2024). This capability is particularly valuable for small-scale inland fisheries where detailed ground surveys are often impractical or cost-prohibitive.

Mapping Habitats and Identifying Optimal Zones

For aquaculture, satellite imagery helps identify productive regions by assessing crucial environmental factors. These include sea surface temperature (SST), plankton abundance (a key indicator of food availability), and water clarity. This “ocean intelligence” significantly reduces guesswork, guiding better siting decisions for farms and ensuring optimal locations for species

like oysters and mussels. For instance, in the Damariscotta River estuary, satellite data from Landsat-8 and Sentinel-2 were used to calculate oyster habitat suitability indices (Jiang et al 2022). This allowed researchers to generate seasonal maps of growing conditions and provide historical environmental data dating back to 2016, offering farmers a data-driven approach that is far more efficient than traditional trial-and-error methods.

Beyond surface mapping, advanced technologies are also revolutionizing our understanding of submerged environments. Airborne topobathymetric LIDAR (Light Detection and Ranging) is used to map submerged topography under lakes, rivers, and reservoirs. This detailed underwater mapping is crucial for understanding the physical structure of fish habitats, which directly influences fish distribution and behavior.

Monitoring Water Quality for Ecosystem Health

Remote sensing offers a powerful solution for continuous monitoring of water bodies, overcoming limitations of traditional methods in geographic coverage and frequency. By detecting reflected radiation, mainly in the visible and near-infrared spectra; it can assess key water quality parameters critical to fish health and productivity (Oseke et al., 2021):

- ✓ **Chlorophyll-a (Chl-a):** Indicates algal abundance and potential harmful blooms.
- ✓ **Turbidity & TSS:** Reflects water clarity, affecting fish habitats and health.
- ✓ **CDOM:** Influences water color and light penetration.
- ✓ **Sea Surface Temperature (SST):** Impacts fish metabolism, migration, and spawning.
- ✓ **Secchi Disk Depth (SDD):** A traditional clarity measure now estimated via remote sensing.
- ✓ **Other Parameters:** Includes pH, EC, DO, TN, TP, and COD—some estimated indirectly using correlations or machine learning.

This technology enables real-time, large-scale tracking of water quality trends and pollution dynamics, supporting proactive decisions in site selection, early warnings for algal blooms, and pollution control. It reduces economic loss and environmental harm, promoting sustainable aquaculture and fisheries management.

Table 1: Advanced Remote Sensing Platforms and Their Applications in Inland Fisheries

Platform/Technology	Key Capabilities	Primary Applications in Inland Fisheries
Satellites (Hyperspectral)	High spectral resolution (narrow, continuous bands), global coverage, long-term monitoring.	Detailed water quality monitoring (e.g., specific pollutants, algal blooms), advanced habitat mapping, ecosystem health assessment.
Drones (UAVs)	Flexible deployment, very high spatial resolution, real-time data, cost-effective for localized areas.	Precision habitat mapping, aquaculture monitoring (cages, feeding, health), fish stock assessment (counting, sizing), illegal fishing surveillance.
LIDAR	Depth profiling of water bodies (bathymetry), fish density estimation, underwater habitat mapping.	Mapping submerged topography in lakes/ rivers, assessing fish biomass, identifying spawning grounds.
Synthetic Aperture Radar (SAR)	All-weather, day/night imaging, penetrates clouds, detects surface roughness/vessels.	Vessel tracking (even with AIS off), illegal fishing detection, monitoring sea ice and surface slicks.
Artificial Intelligence (AI) / Machine Learning (ML)	Automated data analysis, pattern recognition, predictive modeling, handling complex non-linear relationships.	Enhancing water quality parameter estimation (especially non-optically active), automated fish counting/sizing, advanced vessel recognition for IUU fishing.
Other Uncrewed Systems (USVs, AUVs, ROVs)	Access to remote/dangerous underwater environments, acoustic surveys, seafloor imaging.	Underwater surveillance, scallop/oyster farm monitoring, fish population estimation in deep waters, spawning surveys.

Conclusion

Advanced remote sensing, including satellites, drones, and AI; revolutionizes inland small-scale fisheries by enabling precise monitoring of water quality, habitats, fish stocks, and illegal fishing. This technology overcomes traditional limitations, supporting sustainable management, food security, and millions of livelihoods. While challenges like data complexity and accessibility remain, advancements in sensors, AI, and global collaboration are unlocking its full potential. The future of fisheries management is in the skies, guided by powerful “eyes in the sky.”

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ENTREPRENEURSHIP MANAGEMENT IN AGRICULTURE

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Abstract

Agricultural entrepreneurship, or agri-preneurship, is pivotal in transforming traditional farming into innovative, sustainable, and profitable ventures. This article delves into the nuances of entrepreneurship management within agriculture, highlighting its significance, challenges, and the strategies essential for fostering a robust agri-entrepreneurial ecosystem.

Keywords: Agri-preneurship, Sustainable agriculture, Entrepreneurial principles, Value addition ,Market-driven approaches, Rural development , Innovation in agriculture ,Risk management.

Introduction

The agricultural sector has witnessed a paradigm shift from subsistence farming to market-oriented agribusinesses. Entrepreneurship management in agriculture involves the application of business principles to farming activities, aiming to enhance productivity, profitability, and sustainability.

1. CONCEPTUAL FRAMEWORK

DEFINITION OF AGRICULTURAL ENTREPRENEURSHIP

Agricultural entrepreneurship refers to the process of identifying, developing, and managing agricultural ventures that are innovative and market-driven. It encompasses activities ranging from crop production to agribusiness services.

IMPORTANCE IN THE MODERN ECONOMY

With the global population rising, there's an increasing demand for food security and sustainable

agricultural practices. Entrepreneurship in agriculture addresses these needs by introducing innovative solutions and efficient resource management.

2. KEY COMPONENTS OF ENTREPRENEURSHIP MANAGEMENT IN AGRICULTURE

INNOVATION AND TECHNOLOGY ADOPTION

The integration of technology, such as precision farming, biotechnology, and information systems, plays a crucial role in modern agriculture. Entrepreneurs are at the forefront of adopting and disseminating these technologies.

RISK MANAGEMENT

Agricultural ventures are susceptible to various risks, including climatic, market, and financial uncertainties. Effective risk management strategies are essential for the sustainability of agri-entrepreneurial activities.

MARKET ACCESS AND VALUE CHAINS

Understanding and integrating into value chains enable entrepreneurs to add value to their products, access broader markets, and increase profitability.

3. CHALLENGES IN AGRICULTURAL ENTREPRENEURSHIP

FINANCIAL CONSTRAINTS

Limited access to credit and financial services hampers the growth of agricultural enterprises, especially for smallholder farmers.

INFRASTRUCTURAL DEFICIENCIES

Inadequate infrastructure, such as storage facilities, transportation, and irrigation systems, poses significant challenges to agri-entrepreneurs.

POLICY AND REGULATORY HURDLES

Complex regulatory frameworks and lack of supportive policies can deter entrepreneurial initiatives in agriculture.

- Financial constraints due to limited access to credit and investment.
- Lack of infrastructure such as storage, irrigation, and roads.
- Inadequate training and extension services.
- Policy and regulatory bottlenecks.
- Market access difficulties and volatile prices.

- Addressing these issues requires integrated support from governments, financial institutions, NGOs, and research organizations.

4. STRATEGIES FOR ENHANCING ENTREPRENEURSHIP IN AGRICULTURE CAPACITY BUILDING AND EDUCATION

Training programs and educational initiatives can equip aspiring entrepreneurs with the necessary skills and knowledge.

ACCESS TO FINANCE

Developing financial instruments tailored for agricultural ventures, such as microfinance and crop insurance, can alleviate financial barriers.

POLICY REFORMS

Implementing policies that support innovation, ease of doing business, and investment in agriculture can foster entrepreneurial growth.

- Capacity building through education, training, and extension programs.
- Facilitating access to finance and insurance schemes tailored to farmers' needs.
- Promoting innovation through agri-tech and startup incubation centers.
- Improving infrastructure and logistics to connect farmers to markets.
- Simplifying policies and regulations to create an enabling environment for agripreneurs.

5. CASE STUDIES

DIGITAL PLATFORMS IN AGRICULTURE

The development of mobile applications, like the 'Crab Farming' app by Krishi Vigyan Kendra (KVK) in Ganjam, Odisha, exemplifies how technology can empower farmers and promote entrepreneurship in aquaculture.

ORGANIC FARMING INITIATIVES

Entrepreneurs transitioning to organic farming have tapped into niche markets, meeting consumer demand for sustainable and health-conscious products.

Conclusion

Entrepreneurship management in agriculture is a catalyst for rural development, food security, and economic growth. By addressing challenges and leveraging opportunities, agri-entrepreneurs can transform the agricultural landscape.



- In India, startups like AgroStar and DeHaat offer mobile platforms to provide farmers with access to quality inputs, expert advice, and market linkages.
- In Africa, digital tools such as FarmDrive and iCow have empowered smallholder farmers by improving record keeping and access to financial services.
- Organic farming ventures in Europe demonstrate how value-added agricultural products can tap into premium markets and generate sustainable incomes.

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CARBON FOOTPRINTING AND ITS IMPACT ON THE GLOBAL FISHERIES SECTOR

Article ID: AG-VO5-I06-05**Soumya Rai¹, Dr. Sona Dubey², Hariom Bohare^{3*} & Anuj Sharma⁴**

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Abstract

Carbon footprinting has become a crucial tool for evaluating the environmental impact of human activities, particularly in the fisheries sector. As the global demand for seafood continues to grow, the sector contributes significantly to greenhouse gas (GHG) emissions through fuel use, aquaculture practices, and complex supply chains. This article explores how carbon footprinting is influencing the fisheries industry by identifying major emission sources and examining their environmental, economic, and social impacts. It also reviews recent developments, such as sustainable certifications and low-carbon innovations, and highlights strategies including technological advances, policy interventions, and shifting consumer preferences. The findings emphasize the need for collaborative efforts among governments, industries, and consumers to support sustainable and climate-resilient fisheries. These integrated approaches are vital to aligning fisheries with global carbon reduction targets and ensuring long-term marine resource sustainability.

Keywords: carbon footprinting, fisheries, greenhouse gas emissions, sustainability, aquaculture, climate change, low-carbon seafood, environmental impact, policy, consumer behavior

Introduction

Carbon footprinting is a critical tool for measuring the environmental impact of human activities by quantifying the total greenhouse gas (GHG) emissions—primarily carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O) in terms of carbon dioxide equivalents (CO₂e) (Wiedmann & Minx, 2008). This method enables organizations and sectors to identify emission sources, evaluate sustainability performance, and implement climate mitigation strategies. Among the various sectors impacted by environmental concerns, the fisheries industry holds particular importance due to its role in global food security, nutrition, employment, and trade, especially for coastal and developing economies (FAO, 2022). However, the sector also contributes significantly to GHG emissions through fuel-intensive fishing operations, processing, refrigeration, and transportation (Parker et al., 2018). The purpose of this article is to examine how carbon footprinting is reshaping the fisheries industry environmentally, economically, and operationally. By analyzing carbon emissions at different stages of the supply chain, the article highlights how this tool can guide sustainable practices and inform policy decisions that support climate-resilient fisheries.

Understanding Carbon Footprinting

Carbon footprinting is the process of quantifying greenhouse gas (GHG) emissions—primarily carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O)—arising from human activities, with all emissions expressed in carbon dioxide equivalents (CO₂e) to reflect their relative global warming potential (Wiedmann & Minx, 2008). As a key sustainability metric, it connects human actions with their environmental consequences and plays a vital role in addressing climate change by supporting emission reduction goals. A widely adopted method for measuring carbon footprints is Life Cycle Assessment (LCA), which evaluates GHG emissions across all stages of a product's or service's life cycle, from resource extraction to end-of-life disposal (Pandey, Agrawal, & Pandey, 2011). Carbon footprinting incorporates both direct emissions (Scope 1), such as those from fuel combustion, and indirect emissions (Scope 2 and Scope 3), such as those from electricity use and supply chains, as classified by the Greenhouse Gas Protocol (WRI & WBCSD, 2004). These standardized approaches ensure consistency, transparency, and comparability, enabling organizations to design effective mitigation strategies and contribute to global sustainability objectives. Methods for measuring carbon footprints in the fisheries sector rely on standardized and scientifically robust approaches to ensure accuracy and

comparability. One of the most widely used methodologies is Life Cycle Assessment (LCA), which evaluates greenhouse gas (GHG) emissions across all stages of a product's life cycle—from raw material extraction, production, and processing to distribution and disposal (Pandey, Agrawal, & Pandey, 2011). This cradle-to-grave analysis helps identify emission hotspots and areas for improvement. Carbon footprinting also distinguishes between direct and indirect emissions. Direct emissions (Scope 1) stem from sources owned or controlled by an organization, such as fuel combustion by fishing vessels, while indirect emissions include Scope 2 (purchased electricity) and Scope 3 (upstream and downstream supply chain activities) (WRI & WBCSD, 2004). To standardize these assessments, carbon accounting frameworks such as the Greenhouse Gas Protocol provide guidelines and tools to quantify, report, and manage emissions systematically. These methods are crucial for ensuring transparency, comparability, and credibility in carbon reporting.

The Fisheries Sector: An Overview

The fisheries sector plays a vital role in global food security, livelihoods, and economic development. It provides a primary source of animal protein for over three billion people worldwide and supports the livelihoods of approximately 60 million people, particularly in developing and coastal regions (FAO, 2022). Additionally, fish and fish products are among the most traded food commodities globally, contributing significantly to international trade and national economies. However, rising global demand for fish, driven by population growth and changing dietary preferences, has placed immense pressure on marine ecosystems, leading to overfishing and habitat degradation (Pauly & Zeller, 2016). The fisheries sector is broadly divided into two types: capture fisheries and aquaculture. Capture fisheries involve the harvesting of wild fish from oceans, seas, and inland waters, while aquaculture refers to the farming of fish, crustaceans, mollusks, and aquatic plants in controlled environments (FAO, 2022). Both subsectors are essential for meeting the world's seafood demand, but they also present unique environmental and sustainability challenges, particularly in terms of resource use and greenhouse gas emissions. The fisheries sector is broadly categorized into two main types: capture fisheries and aquaculture, each playing a distinct role in global food production and sustainability. Capture fisheries involve the harvesting of wild fish from oceans, seas, and inland waters using various gear and methods. These fisheries are a traditional source of seafood and contribute significantly to livelihoods and food security, particularly in coastal and developing

regions. However, they are often associated with concerns such as overfishing, bycatch, and habitat degradation, which can compromise long-term sustainability (Pauly & Zeller, 2016). In contrast, aquaculture refers to the farming of fish, shellfish, and other aquatic organisms in controlled environments such as ponds, tanks, or ocean cages. It has emerged as a rapidly growing sector, driven by rising global demand for seafood and the depletion of wild fish stocks. While aquaculture offers a more stable supply of seafood, it also presents environmental challenges, including water pollution, disease management, and greenhouse gas emissions from feed and energy use (FAO, 2022).

Sources of Carbon Emissions in Fisheries

Carbon emissions in the fisheries sector stem from a variety of sources across capture fisheries, aquaculture, and the associated supply chains. In capture fisheries, the dominant contributor is the fuel used by fishing vessels, particularly in industrial fleets that operate over long distances and for extended periods. These operations are highly energy-intensive, with diesel fuel combustion releasing substantial amounts of CO₂ into the atmosphere (Parker et al., 2018). Additionally, the use of refrigeration systems and cold storage—necessary to preserve fish quality during and after harvest—further adds to emissions due to continuous energy demands (Tyedmers, 2004). Inefficient practices and overfishing also increase emissions by requiring more time and energy to locate and harvest declining fish stocks (Ziegler et al., 2016). In aquaculture, emissions are largely associated with the production and transportation of fish feed, which often includes resource-intensive ingredients like fishmeal and soy (MacLeod et al., 2020). Energy used for maintaining water quality—through aeration, circulation, and temperature control—also contributes significantly to GHG outputs. Furthermore, the application of fertilizers, antibiotics, and other chemicals can indirectly lead to emissions through manufacturing and usage processes. Beyond production, the fisheries supply chain introduces additional emissions through packaging, processing, cold storage, and global transport, particularly air freight for exports. These logistics operations demand significant energy and contribute to the overall carbon footprint of seafood products (Avadí & Fréon, 2013). Addressing emissions across this entire value chain is essential for improving the sustainability of the fisheries sector. In aquaculture, one of the most significant contributors to the carbon footprint is **fish feed production**. The manufacturing and transportation of feed, particularly when it includes fishmeal or soy-based ingredients, generate substantial greenhouse gas emissions due to

land use change, processing energy, and international shipping (Naylor et al., 2021). Additionally, **energy use for water circulation and aeration** in intensive farming systems further elevates emissions, especially in land-based or recirculating aquaculture systems (RAS) that rely heavily on electricity for pumps, oxygenation, and temperature control (Badiola et al., 2018). The **application of fertilizers and chemicals**, often used to maintain water quality and prevent disease in aquaculture ponds, also contributes to environmental impact through the release of nitrous oxide (a potent greenhouse gas) and the embedded emissions in the production and transport of these substances (Bosma et al., 2017). Together, these operational requirements make aquaculture a sector with notable, though variable, carbon intensity depending on the practices and technologies employed.

Effects of Carbon Footprinting on the Fisheries Sector

Carbon footprinting has wide-ranging effects on the fisheries sector, encompassing environmental, economic, policy, and social dimensions. **Environmentally**, greenhouse gas (GHG) emissions from fisheries contribute directly to climate change, leading to global warming and ocean acidification—two major threats to marine ecosystems (Gattuso et al., 2015). Rising ocean temperatures and changing pH levels disrupt fish habitats, breeding grounds, and migration patterns, ultimately affecting species distribution and reducing biodiversity (Cheung et al., 2013). These shifts can alter catch availability and further strain already overexploited marine resources.

Economically, the drive to monitor and reduce carbon footprints has led to rising operational costs, especially due to increasing fuel prices and the need to invest in more energy-efficient technologies and sustainable practices. In some regions, carbon pricing mechanisms such as carbon taxes or emissions trading schemes have added regulatory costs to fisheries operations (FAO, 2018). At the same time, markets are evolving to favor sustainably sourced, low-carbon seafood products. Eco-labeling and carbon footprint certifications have become important market differentiators, influencing consumer purchasing decisions and creating new market pressures for producers to lower their emissions (Pelletier & Tyedmers, 2008).

Socially, small-scale fisheries—often lacking the resources to adapt—face heightened challenges. Compliance with environmental regulations and sustainability standards can be burdensome for these operators, potentially reducing their competitiveness and threatening their livelihoods (Allison et al., 2009). Coastal communities that heavily rely on fisheries for food

security and employment are particularly vulnerable, as climate-related disruptions and policy shifts may reduce access to resources and income opportunities. Moreover, growing consumer awareness of climate change and sustainability is influencing dietary trends, shifting preferences toward environmentally responsible seafood, which in turn can reshape market dynamics and marginalize less sustainable producers.

Recent Developments and Case Studies

In recent years, the fisheries sector has seen significant advancements in sustainability practices, particularly through the adoption of carbon footprinting and certification systems. Sustainable seafood certifications such as the Marine Stewardship Council (MSC) and the Aquaculture Stewardship Council (ASC) have gained global recognition for promoting environmentally responsible fishing and farming practices, including efforts to reduce carbon emissions across supply chains (Bush et al., 2013). These certifications not only encourage best practices in resource management but also cater to the growing consumer demand for low-carbon and eco-labeled seafood. On a national and regional level, several countries and governing bodies have begun integrating carbon tracking into fisheries policy. For instance, Norway and members of the European Union have implemented carbon accounting frameworks within their seafood industries to support emissions monitoring and promote transparency (Winther et al., 2020). Additionally, various low-carbon initiatives in fisheries and aquaculture are emerging. Examples include the adoption of energy-efficient vessels, feed innovations that reduce emissions in aquaculture, and integrated multi-trophic aquaculture (IMTA) systems that optimize resource use and lower environmental impact (Chopin et al., 2012). These developments illustrate a shift toward climate-conscious seafood production, aligning industry practices with global sustainability goals.

Strategies for Carbon Footprint Reduction

Reducing the carbon footprint in the fisheries sector involves a combination of technological, policy, and market-driven strategies. Technological innovations are at the forefront, including the electrification of fishing vessels to replace fossil fuel engines, the integration of renewable energy sources in aquaculture operations, and the use of artificial intelligence (AI) and the Internet of Things (IoT) to optimize fishing and farming efficiency, thereby minimizing emissions (Sala et al., 2021). On the policy front, international guidelines such as the FAO Code of Conduct for Responsible Fisheries provide a framework for sustainable

practices, while many countries have set national carbon reduction targets that encourage the fisheries sector to adopt cleaner technologies and sustainable methods. Subsidies and financial incentives further support these transitions by making low-emission practices more economically viable (FAO, 2018). Additionally, consumer awareness is driving market shifts, with the rise of carbon labeling on seafood products enabling consumers to make environmentally informed choices. This shift supports local and low-impact fishing practices that tend to have smaller carbon footprints and promote sustainable livelihoods (Roheim et al., 2018). Together, these strategies are crucial for aligning fisheries with global climate goals and ensuring the sector's long-term sustainability. Technological innovations are playing a crucial role in reducing the carbon footprint of the fisheries sector. One of the key advancements is the electrification of fishing vessels, which replaces traditional diesel engines with electric propulsion systems. This shift significantly reduces greenhouse gas (GHG) emissions, improves fuel efficiency, and decreases operational noise, thereby contributing to lower environmental impact (Parker et al., 2018). In aquaculture, the integration of renewable energy sources such as solar and wind power is gaining momentum. These energy solutions help reduce reliance on fossil fuels for critical operations like water aeration, temperature control, and circulation systems (MacLeod et al., 2020). Additionally, emerging technologies like artificial intelligence (AI) and the Internet of Things (IoT) are being employed to optimize feeding, monitoring, and harvesting processes. These smart systems enhance operational efficiency and reduce waste, ultimately contributing to lower emissions and better resource management (Sala et al., 2021). Collectively, these innovations are essential for transitioning toward low-carbon and sustainable fisheries. Policy and regulatory frameworks are fundamental to guiding and enforcing carbon footprint reduction in the fisheries sector. International guidelines, such as the Food and Agriculture Organization's (FAO) *Code of Conduct for Responsible Fisheries*, provide a comprehensive foundation for sustainable practices, emphasizing the need to minimize environmental impact, including greenhouse gas (GHG) emissions (FAO, 1995). Many countries have also adopted national carbon reduction targets aligned with the Paris Agreement, encouraging the fisheries industry to adopt cleaner technologies, energy-efficient practices, and sustainable resource management (UNFCCC, 2015). To support these transitions, governments increasingly offer subsidies, tax incentives, and grant programs aimed at promoting low-emission practices in both capture fisheries and aquaculture. These incentives can help offset the costs of upgrading equipment,

investing in renewable energy, or obtaining sustainability certifications (FAO, 2018). Together, such policy measures create an enabling environment that not only supports climate goals but also enhances the long-term viability of the fisheries sector. Consumer and market shifts are playing an increasingly influential role in driving carbon footprint reduction in the fisheries sector. The growing demand for transparency and sustainability has led to the rise of carbon labeling on seafood products, enabling consumers to make informed choices based on the environmental impact of their purchases (Roheim et al., 2018). These labels often reflect the carbon emissions associated with production, processing, and transportation, incentivizing producers to adopt low-emission practices to remain competitive in environmentally conscious markets. Additionally, there is a growing preference for locally sourced, low-impact seafood, which typically has a smaller carbon footprint due to reduced transportation distances and more sustainable harvesting methods (Jacquet & Pauly, 2008). These consumer trends not only support environmentally responsible fisheries but also bolster small-scale, community-based operations that prioritize ecological balance. Ultimately, shifting consumer behavior is a powerful force that encourages the industry to align more closely with global sustainability and climate goals.

Conclusion

Addressing carbon emissions in the fisheries sector is crucial for mitigating climate change and ensuring the long-term health of marine ecosystems. As a key provider of food, employment, and economic value worldwide, the fisheries industry must adapt to the growing environmental challenges posed by greenhouse gas emissions. Emphasizing sustainable development through technological innovation, regulatory frameworks, and responsible consumer behavior is essential for reducing the sector's carbon footprint. A coordinated, multi-stakeholder approach—bringing together governments, industry leaders, and consumers—is necessary to foster resilience, promote eco-friendly practices, and secure the future of global fisheries in an increasingly carbon-conscious world.

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ARTIFICIAL INTELLIGENCE AND MACHINE LEARNING IS ENHANCING AQUACULTURE PRODUCTION

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Abstract

As global demand for aquatic protein intensifies, traditional aquaculture struggles with sustainability, efficiency, and disease management. Artificial Intelligence (AI) and Machine Learning (ML), particularly when integrated with the Internet of Things (AIoT), offer transformative solutions across water quality monitoring, precision feeding, growth prediction, and disease prevention. Techniques like computer vision, reinforcement learning, and predictive analytics are revolutionizing farm operations, minimizing waste, improving feed conversion, and reducing mortality. Applications extend to emerging sectors like seaweed farming through biomass estimation and digital twins. AI not only enhances productivity and environmental stewardship but also supports economic viability and social adaptation. By shifting aquaculture from manual, intuition-driven methods to data-informed decision-making, AI represents a strategic imperative for ensuring food security and ecosystem resilience. The sector's future depends on embracing intelligent, scalable technologies that optimize resources while preserving environmental integrity.

Keywords; Water Quality, Disease Detection, Smart Aquaculture, Sustainability

Introduction

The aquaculture industry stands at a pivotal juncture, grappling with the escalating global demand for aquatic protein while simultaneously confronting severe environmental challenges. Since 1961, the consumption of aquatic products has surged at twice the rate of population growth, placing immense pressure on marine fishery resources already strained by overfishing, habitat degradation, pollution, and the pervasive impacts of climate change. Traditional



aquaculture methods, often reliant on manual processes and intuition, are proving insufficient to meet these burgeoning requirements sustainably. The industry faces persistent hurdles, including operational inefficiencies, complex disease management, and the imperative for responsible resource optimization.

In response to these multifaceted pressures, Artificial Intelligence (AI) and Machine Learning (ML) are emerging as transformative technologies, offering innovative solutions for monitoring, management, and conservation across the entire aquaculture and fisheries spectrum. The integration of AI with the Internet of Things (IoT), collectively known as the Artificial Intelligence of Things (AIoT), is particularly impactful, providing continuous streams of data on critical environmental and biological parameters. These technological advancements are facilitating a fundamental shift from traditional, labor-intensive farming practices to data-driven decision-making, promising enhanced efficiency, sustainability, and profitability.

Despite aquaculture sector's economic significance, it contends with considerable challenges related to inefficiencies, waste, and disease outbreaks. The successful implementation of AI and ML in addressing these specific issues within fish farming provides a compelling blueprint and a scalable model for the broader application of these advanced technologies across the entire aquaculture landscape.

The increasing global demand for aquatic protein, coupled with mounting environmental degradation, underscores a critical imperative for the aquaculture sector to embrace AI. The article highlights a dual pressure, a rapidly growing global population requiring more food and marine ecosystems under severe stress from human activities and climate change. Traditional aquaculture, as currently practiced, cannot sustainably bridge this gap. Therefore, AI is not only an incremental improvement; it represents a strategic necessity for the industry to scale responsibly and contribute effectively to global food security. Entities that fail to integrate AI risk falling behind in meeting future food demands and adhering to evolving environmental regulations, potentially compromising their long-term viability. At its heart, machine learning is about teaching computers to learn from data without being explicitly programmed. Think of it like this: instead of writing a rule for every possible scenario, you give the computer a vast amount of past information, and it figures out the rules itself. In aquaculture, this "data" comes from a myriad of sources: environmental sensors, underwater cameras, historical growth records, feed consumption logs, and even genomic information.

Different types of ML models play distinct roles:

- **Supervised Learning:** This is like learning with a teacher. You feed the model labeled data (e.g., images of healthy shrimp vs. diseased shrimp, with labels indicating their condition), and it learns to predict outcomes for new, unlabeled data. This is crucial for tasks like disease diagnosis and growth prediction.
- **Unsupervised Learning:** Here, the model learns from unlabeled data, identifying patterns and structures on its own. It's useful for tasks like grouping shrimp by similar behaviors or identifying anomalous water quality readings that might indicate an issue.
- **Reinforcement Learning (RL):** This involves an "agent" learning through trial and error, receiving rewards for good actions and penalties for bad ones. In aquaculture, RL could potentially optimize complex feeding strategies or automate environmental control systems to maximize yield.
- **Deep Learning (DL):** A subset of ML, deep learning uses artificial neural networks with many layers, allowing them to learn incredibly complex patterns from large, often unstructured data like images and videos. DL is particularly powerful for computer vision tasks such as counting, sizing, and stress detection in aquatic animals.

Here's how AI works in aquaculture:

1. The Sentinel of the Pond: Water Quality Management

Maintaining pristine water quality is paramount for shrimp health. Traditional manual checks are laborious and prone to delays. AI-powered systems, often integrating the Internet of Things (IoT), offer a revolutionary alternative:

- **Real-time Monitoring:** IoT sensors continuously collect data on critical parameters like pH, temperature, dissolved oxygen, ammonia, and salinity. This data is instantly streamed to cloud platforms.
- **Predictive Analytics:** Machine learning models analyze this real-time and historical data to predict fluctuations in water quality. For instance, an IoT-ML system predicts next-day water parameters with 94% accuracy and classifies production levels (low, medium, maximum) with 97.84% accuracy using the Random Forest algorithm (Khan et al., 2022).
- **Automated Adjustments:** When parameters deviate from optimal levels, AI can trigger automated aeration systems, filtration, or alerts to farmers, preventing mass mortality events.

2. Smart Spoons: Optimizing Feed and Growth

- Feed constitutes a significant portion of operational costs in shrimp farming. Overfeeding
Behavioral Monitoring: Underwater cameras and acoustic sensors, combined with computer vision, observe shrimp feeding behavior in real-time. AI can detect when shrimp are actively feeding or when they've had enough, preventing over- or underfeeding.
- **Precision Feeding Systems:** Automatic feeders, guided by AI algorithms, dispense small, controlled amounts of feed at optimal times and frequencies. This not only improves the Feed Conversion Ratio (FCR), how efficiently feed is converted into biomass, but also minimizes waste and its environmental impact. Skretting's precision feeding solutions are a prime example.
- **Growth Prediction Models:** ML models analyze historical growth data, environmental conditions, and feed intake to predict shrimp growth curves with high accuracy. Platforms like Kampi use "Next-Gen Predictive Analytics" and real-time pond weights to track biomass and forecast harvest times, allowing farmers to optimize production planning and resource allocation. Such models can help in making timely decisions regarding sales and logistics, boosting average oyster weight by 15%.

3. Early Warning System: Disease Detection and Prevention

Disease outbreaks can decimate shrimp populations and lead to significant economic losses. AI offers a proactive shield:

- **Computer Vision for Symptom Detection:** Advanced deep learning frameworks, like the Enhanced Recurrent Capsule Network (ERCN), can analyze images of shrimp to detect subtle visual signs of disease or stress. An AI system developed by the Alfred Wegener Institute and Oceanloop, called ShrimpWiz, can count, size (with 95% accuracy), and detect stress in shrimp tails with color-coded alerts (ShrimpWiz, AWI, 2025)
- **Accuracy in Diagnosis:** An AI system published in Scientific Reports achieved 95.2% accuracy in detecting six major shrimp diseases, including White Spot Syndrome Virus and Vibriosis, in just 58 milliseconds per image, even with low-resolution inputs (Chowdhury et al., 2024).

- **Predictive Risk Assessment:** By correlating environmental data with historical disease outbreaks, AI can identify risk factors and predict potential outbreaks, enabling farmers to implement preventive measures or targeted treatments. Machine learning also helps model shrimp income and disease risks, revealing complex, nonlinear relationships those traditional econometric models often miss, offering a more comprehensive view.

Seaweed Cultivation:

Seaweed, a rapidly growing aquaculture sector for food, bioplastics, and biofuels, is also benefiting from AI.

- **Optimized Growth Conditions:** AI processes vast environmental data (temperature, salinity, nutrients, and water motion) to optimize growth conditions, whether in land-based tanks or open ocean farms. This moves seaweed farming from empirical knowledge to data-driven optimization.
- **Predictive Analytics:** AI accelerates R&D by identifying promising strains and forecasting biochemical properties, minimizing costly trial-and-error. It also optimizes supply chains by predicting market demand and logistics.
- **Biomass Estimation:** Machine learning models, combined with advanced sensor technologies like Pseudorandom Encoded Light for Evaluating Biomass (PEEB) sensors, estimate seaweed biomass and predict optimal harvest timing, despite challenges like noisy underwater data.
- **Digital Twin Models:** AI-powered digital twins allow virtual simulation of farming scenarios and scaling operations, predicting environmental impacts and optimizing practices for sustainable growth.

The Future is Smart: Emerging Possibilities and Impacts

- **Beyond Monitoring: Autonomous Farms:** The integration of AI, IoT, and robotics will lead to increasingly autonomous farms where environmental controls, feeding, and even harvesting are managed with minimal human intervention. Underwater drones will conduct automated inspections, detect defects, and identify anomalies, reducing human risk and labor costs.
- **Hyper-Personalized Nutrition:** AI will enable tailored nutrition plans for individual fish or shrimp based on their specific growth rates, health status, and genetic profiles, maximizing growth and minimizing waste.

- **AI-driven Adaptive Gene Health Analysis:** Future systems will integrate high-throughput gene sequencing with deep neural networks to analyze gene expression, predict adaptability under stress, and recommend optimal gene modification for enhanced disease resistance and growth.
- **Quantum Pathogen Detection:** Imagine AI-quantum pathogen detection systems that integrate quantum computing to accelerate gene sequence alignment and predict pathogen outbreaks in real-time using nanobiosensors.
- **Large Models and Federated Learning:** "Foundation Models" will integrate vast, multimodal data (water quality, weather, behavior, and genetics) to create universal intelligent aquaculture systems. Federated learning will allow these models to share optimization strategies across farms while ensuring data privacy.

Economic, Environmental, and Social Impacts:

- **Economic Prosperity:** AI significantly boosts production efficiency by optimizing resource utilization, reducing feed waste (by up to 20%), minimizing mortality rates, and enhancing market access through better supply chain management and demand forecasting. This translates into higher yields and increased profitability for farmers
- **Environmental Stewardship:** By optimizing feeding, AI reduces nutrient pollution in water bodies and the seafloor. Smart siting and management practices, guided by AI, prevent harmful algal blooms and minimize impacts on benthic environments. AI-driven sustainability tools contribute to responsible feed sourcing and can even assess environmental impact (Nti et al.,2023)
- **Social Evolution:** AI in aquaculture is a crucial step towards global food security, providing a sustainable protein source for a growing population. While concerns about job displacement exist, experts emphasize that AI is more about *augmenting human productivity* rather than replacing it. It shifts labor from strenuous manual tasks to skilled roles in data analysis, system management, and technological development. However, challenges remain in addressing data security and privacy, building stakeholder trust through transparency, and bridging knowledge and training gaps for effective AI adoption.



Conclusion

Machine learning is not merely a technological upgrade for aquaculture; it is a fundamental shift in how we approach food production from the oceans and freshwaters. By empowering farmers with data-driven insights and automated tools, AI is paving the way for a more resilient, sustainable, and productive aquaculture industry, ensuring that the bounty of the waters can feed generations to come. The AI tide is here, and it's set to revolutionize the way we farm our aquatic future.

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BOTANICA OF SESAME

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Introduction

Sesame (*Sesamum indicum* L.) is the oldest indigenous oilseed crop, with longest history of cultivation in India. Sesame or gingelli is commonly known as til (Hindi, Punjabi, Assamese, Bengali, Marathi), tal (Gujarati), nuvvulu, manchi nuvvulu (Telugu), ellu (Tamil, Malayalam, Kannada), tila/pitratarpana (Sanskrit) and rasi (Odia) in different parts of India. Sesame seed (contain 50% oil, 25% protein and 15% carbohydrate) is used in baking, candy making and other food industries. It is an integral part of rituals, religion and culture. The oil is used in cooking, salad oils and margarine (contains about 40% oleic and 40% linoleic acid). Sesame oil and foods fried in sesame oil have a long shelf life because the oil contains an antioxidant called sesamol. The oil can be used in the manufacture of soaps, paints, perfumes, pharmaceuticals and insecticides. Sesame meal is an excellent high quality protein (40%) feed for poultry and livestock. Sesame seeds are store house of energy and very rich in vitamins E, A, B Complex and minerals viz., calcium, phosphorus, iron, copper, magnesium, zinc and potassium. It is a best substitute for mother's milk especially in case of milk allergies. Sesame seed contains extraordinary quantities of methionine, tryptophan, amino acids with innumerable benefits. The oil is used as the base for Ayurvedic preparations and known as the Queen of oils. Sesame seeds are called as the seed of immortality. Studies showed that lignans found in sesame seed have remarkable antioxidant effect on human body. Til se dil or Til – dil are the ancient Hindi

proverbs in India signifying the importance of sesame for heart. Sesame oil is considered as anticholesterol and highly beneficial for heart ailments. Sesame is energy rich crop, ironically however, grown on energy starved condition. India ranks first in world with 16.73 Lakh ha area and 6.5 Lakh tonnes production. The average yield of sesame (391 kg/ha) in India is low as compared with other countries in the world. The main reasons for low productivity of sesame are its rainfed cultivation in marginal and submarginal lands under poor management and input starved conditions. However, improved varieties and agro production technologies capable of increasing the productivity levels of sesame are now developed for different agro ecological situations in the country. A well managed crop of sesame can yield 1200-1500 kg/ha under irrigated and 800-1000 kg/ha under rainfed conditions. The crop is grown in almost all parts of the country. The area, productivity of the important states growing sesame during 2012-13 is given in Tables

Area of major sesame growing states ('000 hectares)

State	1965-66	1975-76	1985-86	1995-96	2005-06	2011-12	2012-13*	% Change over 1965-66
Andhra Pradesh	224.20	136.10	152.30	199.40	116.00	72.00	67.0	-70.12
Gujarat	111.30	106.90	126.80	249.70	364.00	247.00	133.0	19.50
Madhya Pradesh	346.50	259.50	233.00	182.50	150.10	294.90	314.5	-9.24
Maharashtra	117.80	171.10	227.30	194.80	107.00	46.00	31.0	-73.68
Rajasthan	630.00	366.90	520.00	329.40	422.10	512.80	415.2	-34.10
Uttar Pradesh	708.00	674.20	278.00	195.60	107.10	345.00	345.0	-51.27
West Bengal	8.20	33.30	74.80	115.30	146.00	182.10	187.5	2186.59
All India	2480.0	2170.0	2217.0	1825.7	1723.2	1901.5	1673	-32.54

*Estimates

Source: All India Co-ordinated Research Project on Sesame and Niger –ICAR, JNKW Campus, Jabalpur: PP: 04

CLIMATIC REQUIREMENT

Sesame is grown in almost all the states in large or small areas. It can be cultivated up to the latitude of 1600m (India 1200 m). Sesame plant needs fairly high temperature during its life cycle. Normally the optimum temperature required during its life cycle is between 25-35⁰C. If the temperature is more than 40 0C with hot winds the oil content reduces. If the temperature goes beyond 45 0C or less than 15 0C there is a severe reduction in yield. The pollen become sterile at aberrant temperatures. The crop is very sensitive to excessive water in the field. Stagnation of water for long period in the standing crop will completely affect the crop. The well distributed rain during kharif season results in the good crop. During the last decade drastic changes in the climate have been experienced in the country. Aberrations in weather conditions, irregular and unevenly distributed rainfall have adverse effect on sesame yield. The abiotic stresses consequently will result in the biotic stresses which are difficult to manage. In order to tackle these problems one should evolve appropriate varieties to tolerate abrasive weather conditions. Photo and thermo insensitive varieties, responsive to fertilizer application depending on moisture and resistant varieties to insect pests and diseases are the need of the hour.

Productivity of major sesame growing states (Kg/ha):

State	1965-66	1975-76	1985-86	1995-96	2005-06	2011-12	2012-13*	% Change over 1965-66
Andhra Pradesh	185.00	194.00	202.00	271.00	250.00	278.00	328.00	77.30
Gujarat	231.00	390.00	155.00	370.00	393.00	474.00	256.00	10.82
Madhya Pradesh	155.00	156.00	200.00	254.00	387.00	525.00	500.00	222.58
Maharashtra	231.00	230.00	220.00	249.00	271.00	326.00	290.00	25.54
Rajasthan	82.00	177.00	52.00	104.00	149.00	324.00	294.00	258.54
U.P.	179.00	128.00	60.00	130.00	252.00	217.00	186.00	3.91
W. Bengal	500.00	622.00	588.00	787.00	843.00	918.00	941.00	88.20
All India	171.00	221.00	226.00	291.00	372.00	426.00	391.00	128.65

*Estimates

Source: Directorate of Oil Seeds Development , Himayat Nagar, Hyderabad

GROWING SEASONS: Sesame is grown in all the crop growing seasons viz, kharif, late kharif, rabi and summer. It is grown in more than one season in some part and in different seasons in other parts of the country.

season	Planting time	Harvesting time	Situation	Area (%)	Names of states
Rainy (Kharif)	June- July	Oct-Nov	Rainfed	70	Rajasthan, Uttar Pradesh, Madhya Pradesh, Gujarat, Andhra Pradesh, Maharastra, Odisha, Tamil Nadu and Karnataka
Late (Kharif)	Aug-Sept	Dec-Jan	Rainfed	10	Andhra Pradesh, Gujarat, Madhya Pradesh and Maharastra
Winter (rabi)	Oct-Nov	Feb-March	Irrigated	Rare	Tamil Nadu, Andhra Pradesh and Odisha
Summer	Jan-March	April-June	Irrigated	20	West Bengal, Odisha Gujarat, Andhra Pradesh, Tamil Nadu and Kerala
Pre Kharif	Apr-May	July	Rainfed	10	Karnataka, Andhra Pradesh

Source: All India Co-ordinated Research Project on Sesame and Niger –ICAR, JNKW Campus, Jabalpur: PP: 13

Normally, the crop is grown in plains but it also comes up successfully up to 1200 m above mean sea level. For maximum yield, sesame requires fairly high temperatures (25-35°C) and evenly distributed rainfall during its growth period. **SOILS:** Sesame can be grown on a wide range of soils, however well drained light to medium textured soils are preferred. It does best on sandy loams with adequate moisture. The optimum pH range is 5.5 to 8.0. Acidic or alkaline soils are not suitable.

Description General: Sesame (*Sesamum orientale*) is an introduced annual broadleaf plant that grows 5–6 ft (155-185 cm) tall. It produces a 1–2 in (2.5–5cm) long white, bellshaped inflorescence growing from the leaf axils (where the leaf stalk joins the stem). The blooms do

not open all at once, but gradually, from the base of the stem upwards to the top of the plant. The flowers are both male and female and will self-pollinate.



SEED: The seed is produced in a 1–1.5 in (2.5–3.8 cm) long, divided seed capsule that opens when the seeds are mature. There are 8 rows of seed within each seed capsule, and seed may be yellow, white, brown, or black (Morris, 2002). Due to the nonuniform, indeterminate nature of the bloom period, the reproductive, ripening, and drying phases of the seed tend to overlap. Seed lowest on the plant will mature first, even as the upper part of the plant is still flowering or has just formed seed capsules. Sesame varieties have single or multiple stems. The stem is covered with short, soft hairs. Sesame is very leafy; with 3–5 in (7.5–12.7 cm) long, somewhat rough, lance shaped, entire upper leaves, and tri-lobed lower leaves. Sesame has been grown in many parts of the world for over 4000 years. First introduced in the southern United States by slaves, the plant's potential as an oil seed was quickly recognized and enthusiastically promoted by Thomas Jefferson. Currently, the United States imports more sesame than it grows, so there is potential for increasing production acres in the US, especially as more shatter-resistant varieties are developed.



Distribution

Sesame is most commonly planted in the south and south western United States, but is also being promoted in the southeast because it grows well in hot weather and sandy soils. For current distribution, please consult the Plant Profile page for this species on the PLANTS Web site.

Habitat: Sesame grows best in well-drained, sandy loam soils, with a pH from 5–8. Sesame cannot survive standing water or high salinity environments.

Adaptation

Sesame is notable for its ability to grow under droughty conditions and in extreme heat. It is often grown where cotton can grow, under conditions few other crops can survive, requiring very few inputs. These attributes make sesame an excellent candidate for low-input sustainable food systems. Sesame is deep-rooted and will scavenge nutrients from below most crop root zones (Langham et al., 2008). When grown from East Texas to the Atlantic coast sesame becomes more susceptible to leaf diseases (Langham et al., 2008). Sesame has moderate salt tolerance (Bahrami and Razmjoo, 2012), but will not grow under flooded conditions. Generally, the plant will have a better chance of survival when it is grown in hotter than optimal temperatures rather than lower than optimal temperatures (Langham et al., 2008).

Uses Forage/Feed

Sesame seed meal is high in protein and can be used to feed livestock and chickens. In aquaculture systems, sesame oil cakes have similar protein content to soybean meal and are successfully used as a fishmeal protein substitute without negatively affecting the growth of carnivorous fish (Thu et al., 2011). Two separate studies, one with rainbow trout (Thu et al., 2011) and another with great sturgeons (Jahanbakhshi et al., 2012), found that almost half of these fishes' diet of fishmeal could be substituted with sesame oil cake.

Cover crop/green manure

Sesame is a vigorous summer annual that can be grown as a cover crop to improve soil structure (Myers, 2002). Sesame can increase yields in subsequent cash crops by successfully improving soil moisture retention and soil tilth (Langham et al., 2008). Sesame, similar to sunn hemp and sorghum-sudangrass, can successfully reduce root-knot nematode populations in subsequent crops (Sipes and Arakaki, 1997; McSorley, 1999; RodriguezKabana et al., 1988). Sesame has a higher C:N ratio than most legume covers, vigorously outcompetes weeds, and may attract beneficial insects (Creamer and Baldwin, 2000). Cotton intercropped with sesame has been shown to regulate cotton bollworm/corn earworm (Pimbert, 2003). Sesame has also been used extensively in hybrid poplar agroforestry systems in China (Gold and Hanover, 1987).
Phytoremediation: Sesame plants have been used to successfully accumulate and remove from the soils the broad-spectrum organochlorine pesticide lindane, a neurotoxin that can persist in

soils for many years (Abhilash and Singh, 2010).

Wildlife: Sesame seed is eaten by songbirds, quail, and doves.

Ethnobotany

Sesame seed has a long history of use for its oil as well as other food products such as bread and bakery items. Approximately 70% of worldwide seed production is processed into oil and meal (Morris, 2002). The seed has excellent nutritional value (Bahrami and Razmjoo, 2012), is high in fat and protein content, and is valued as a cooking oil because it has higher levels of antioxidants than other cooking oils (Myers, 2002). Japan considers sesame a health food and leads the world in imports (Morris, 2002). The seed can be eaten raw or roasted. White sesame seed from Mexico, Guatemala, and El Salvador is consumed at rates twice that of black sesame seed from China and Thailand (Morris, 2002). soils can improve germination and seedling growth.

Cultivation

Seed should be planted at 2–3 lb/ac at $\frac{3}{4}$ –1½ in deep in late spring/early summer, when soils are sufficiently warm. It grows slowly in the seedling stage so may require cultivation for weed control. If weeds are going to be cultivated, 18 to 30-inch rows should be planted. Both row planters and seed drills can be used to establish stands. No-till planting may increase soil surface moisture at time of planting, but sesame is a small seed, and may not achieve good soil to seed contact. Generally, row spacing is determined by farmer preference for weed cultivation and whether or not irrigation is available. Wider row spacing is recommended for weed cultivation and when planting in drier fields with less irrigation (Langham et al., 2008). Since sesame is a low input crop, using a leguminous cover crop or animal manure prior to establishment can provide enough nitrogen for following sesame crop (Myers, 2002). If fertilized, the last application of fertilizer should be applied no later than the prereproductive stage (just after first green buds emerge). If soil amendments are used, their use should be based on recommendations provided by soil testing laboratories and/or cooperative extension. The last irrigation should be no later than the late bloom stage.

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THE CARBON MARKET IN AGRICULTURE

Article ID: AG-VO5-I06-08**Elumle Priyanka^{1*}, Ashwini Bhosale² and Kailas Bhalerao²**¹Young Professional-II, KVK, Bellampalli (PJTAU)² Asst Professor, Department of Horticulture, College of Agriculture, Khandala (VNMKV)

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Abstract

The carbon market in agriculture is an emerging system that rewards farmers for practices that reduce greenhouse gas emissions or increase carbon sequestration in the soil. It essentially allows agricultural producers to earn money by being climate-friendly. A carbon market is a system that allows the buying and selling of carbon credits which represent the reduction or removal of greenhouse gases from the atmosphere. Each carbon credit equals one metric ton of carbon dioxide (CO₂) or its equivalent in other greenhouse gases that has either been prevented from being emitted or has been absorbed from the atmosphere. These credits are valuable because they help organizations such as companies or governments offset their own emissions. By purchasing these credits, they can meet environmental targets or regulatory requirements aimed at combating climate change. The carbon market thus creates a financial incentive for individuals and industries to adopt eco-friendly practices and invest in sustainable technologies.

Introduction

In today's world, where climate change is one of the biggest threats we face, Farmers traditionally known for feeding the world are now being recognized for something equally vital, their ability to combat climate change. Agriculture is no longer just about cultivation of crops and improving yield but also about capturing carbon and cutting emissions by getting paid. This emerging system allows them to earn money by adopting practices that either reduce greenhouse gas emissions or store more carbon in the soil. At the heart of this system are carbon credits tradable permits that represent one metric ton of carbon dioxide (or its equivalent) kept out of the

atmosphere. Companies and governments buy these credits to offset their own emissions and meet environmental goals (White & Case LLP. (2020). By purchasing credits, they offset their own pollution while supporting sustainable farming practices (*Ministry of Agriculture and Farmers Welfare* (2024)). This creates a win-win situation, the environment benefits from lower emissions and farmers gain a new stream of income. That means when a farmer plants cover crops, reduces tillage or improves soil health they can earn carbon credits and profit from climate-friendly farming. In simple terms carbon credits are bought and sold. Each credit represents one metric ton of carbon dioxide (CO₂) or its equivalent in other greenhouse gases that has either been removed from the atmosphere or prevented from being released. This article explains how the carbon market works, what it means for agriculture and why it could be a game-changer for both the environment and rural economies.

How the Carbon Market Works in Agriculture

Farmers adopt eco-friendly practices like conservation tillage, cover cropping, organic mulching, integrated nutrient management, crop rotation, agroforestry and efficient use of water and fertilizers. These methods help reduce greenhouse gas emissions or store more carbon in the soil. These sustainable actions either lower emissions of gases like methane (CH₄) and nitrous oxide (N₂O) or increase soil organic carbon helping to combat climate change.

Measurement, Reporting and Verification (MRV)

The amount of carbon saved or stored is measured, reported and verified by an independent third party to ensure accuracy and transparency.

Types of Carbon Markets

Based on regulation, There are two types of carbon credit systems based on regulatory oversight compliance markets and voluntary markets. (CarbonCredits)

1. Compliance Carbon Market

The compliance market also known as the regulated carbon market is governed by national or international climate policies and laws. It is designed to help countries and industries meet legally binding greenhouse gas (GHG) emission reduction targets. One of the most well-known examples is the European Union Emissions Trading System (EU ETS). In these markets, companies are given a cap on how much CO₂ they can emit. If they stay below their limit, they can sell excess allowances. If they go over, they must buy more or face penalties. Although this system plays a crucial role in curbing industrial emissions, agriculture currently has limited

participation in compliance markets mainly due to complexities in measuring emissions and sequestration accurately in farm systems. However, with growing interest in sustainable agriculture, future regulations may bring more opportunities for farmers.

2. Voluntary Carbon Market

The voluntary carbon market operates outside of legal mandates and is driven by private companies, organizations and individuals who choose to offset their carbon emissions for ethical, environmental or branding reasons. This market is more flexible and innovative, making it the primary platform for agricultural carbon credits. In this system, when farmers adopt climate-smart practices like cover cropping, reduced tillage or agroforestry, the carbon they sequester or emissions they reduce can be verified and converted into carbon credits. These credits can then be sold to buyers in the voluntary market. This model creates a direct financial incentive for farmers to adopt sustainable practices, and it allows environmentally conscious businesses to support agriculture-based climate solutions while offsetting their own emissions.

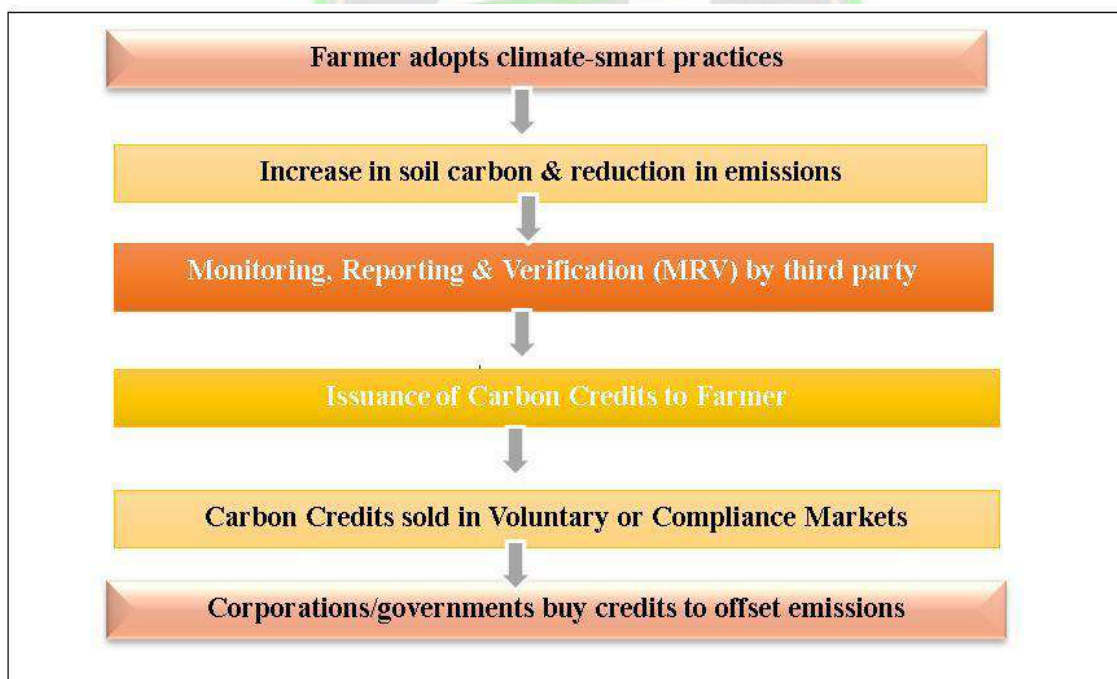


Figure: Stepwise Mechanism of Carbon Credit Generation in Agriculture through Climate-Smart Practices

Benefits for Farmers

Participating in the carbon market offers several valuable benefits for farmers. The most direct advantage is the creation of a new income stream through the sale of carbon credits. By adopting climate smart practices like reduced tillage, cover cropping or agroforestry, farmers can earn credits that are sold to companies seeking to offset their emissions. Beyond financial gains, these practices also lead to improved soil health which in turn enhances crop productivity and reduces the need for chemical inputs (*Ministry of Agriculture and Farmers Welfare (2024)*). As a result, farms become more resilient to climate change, better able to withstand droughts, floods and extreme weather. Additionally, farmers who engage in these sustainable efforts are increasingly being recognized as climate stewards, gaining respect and visibility for their vital role in addressing global environmental challenges.

Challenges for Farmers in the Carbon Market

1. **High Cost of MRV (Monitoring, Reporting and Verification):** Ensures accuracy of carbon savings but is expensive and technically demanding.
2. **Uncertainty in Carbon Credit Pricing:** Fluctuating market prices make it difficult for farmers to estimate financial returns.
3. **Complexity in Carbon Accounting:** Calculating emissions reductions or soil carbon sequestration is technically complex especially for smallholders.
4. **Lack of Awareness and Training:** Many farmers are unfamiliar with how carbon market's function and how to participate effectively.
5. **Lack of Standardized Agricultural Protocols:** Inconsistent rules across different carbon projects create confusion and hinder credit validation.

Future Scope of Carbon Markets in Agriculture

1. **Government and NGO Support:** Public and private institutions are working to develop platforms, policies and financial incentives to help farmers participate in carbon markets more easily.
2. **Emerging Technologies:** Tools like remote sensing, blockchain and artificial intelligence (AI) are being integrated to simplify and reduce the cost of tracking carbon sequestration and emissions reductions on farms.

3. **National Carbon Market Policies:** Countries like India are actively developing national carbon trading frameworks, where agriculture is expected to play a significant role in meeting climate goals and generating rural income.
4. **Increased Role in National Climate Strategies:** Countries like India, the US, and members of the EU are integrating agriculture into their national carbon trading systems, recognizing the sector's potential to contribute significantly to emissions reduction targets.
5. **Standardization and Certification:** Development of uniform standards and certification protocols for agricultural carbon credits will improve market transparency, trust and accessibility.
6. **Integration with Sustainable Development Goals (SDGs):** Carbon market participation will align with broader environmental, social and economic goals, including soil health, biodiversity conservation, and rural livelihoods.

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DODONAEA VISCOSA- AN UNDERUTILIZED SHRUB FOR TRADITIONAL MEDICINAL USE IN HIMACHAL PRADESH

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Introduction

Himachal Pradesh is a hilly state which lies in the lap of North-Western Himalayan range and blessed with different seasons. The state is located between 30° 22' 40" and 33° 12' 40" North Latitudes and 75° 47' 55" to 79° 04' 20" East Longitudes with varying altitude from 350-7000 metres above mean sea level. Floral diversity in the State is comprised of forest vegetation, medicinal and aromatic plants, diversity in agricultural crops including unexploited, underutilized and lesser known cereal crops, wild fruits and wild ornamental plants. The distinctive floral variety in the state played a significant role in socio-economic prosperity of the rural folk. There is 3256 plant species out of total plant species (46,000) present in the country. Natural ecosystem of the state plays a crucial role in distribution and conservation of the floral diversity. *Dodonaea viscosa* is a medium-sized shrub found in lower foothills of the state covering the district Solan, Sirmour, Bilaspur, Una, Hamirpur, Kangra of the state. The shrub is mainly grown in the scrub type of forest exposed to full sunlight. The shrub is almost absent under chir pine forest. The chemical analysis of this plant as reported by various authors contained alkaloids, flavonoids, steroids, phenolic compounds, glycosides, carbohydrates, saponins, tannins, gums, mucillages, fixed oil and fat, reducing sugar and trace elements. The pharmacological studies also showed that it possessed anti-inflammatory, anti-diabetic, antispasmodic, anti-diarrheal wound, analgesic, insecticidal, antioxidant, cytotoxic, antifertility, anti-ulcer, antimicrobial and detoxification effects.

Brief introduction of the plant:**Taxonomic classification:**

Kingdom: Plantae, Sub-kingdom: Viridiplantae, Division: Tracheophyta, Subdivision: Spermatophytina, Class: Magnoliopsida, Order: Sapindales, Family: Sapindaceae, Genus: Dodonaea, Specie: Dodonaea viscosa.

Vernacular Name:

- Sinatha : Hindi, Hop bush: English
- Viraali or Vilaari: Tamil
- Bandare or Bandarike: Kannada
- Bandaru or Bhandara: Telugu and Mohra or Mahada: Oriya
- Local name in HP : Mahendu or Mahendru

Distribution:

Australia is believed to be the centre of origin of this plant although it found throughout the tropics and subtropics region of the country. In Himachal Pradesh, the plant is distributed in subtropical region up to an elevation of 800 meter covering the parts of districts Solan, Sirmour, Bilaspur , Una, Hamirpur, Kangra.

Plant Profile:

Height: In Himachal Pradesh, it is found as a medium-sized shrub up to 10 to 15 feet in height.

Bark:

The plant has several main branches with reddish-brown to blackish grey bark. **Leaves:** Leaves are simple, alternate, spiral, clustered at twig ends, mostly longer than wide and most often pointed (lance-shaped to elliptical). Generally, the leaves are 1 to 4 inches long and glossy green having reddish midribs or stems. The new leaves and sometimes older ones are covered with a sticky substance. The older leaves have a rough, sandpapery texture.

Flowers:

The individual flowers are small, about 1/4 inch in diameter and occur in branched clusters. Flowers are either male or female and only the female flowers develop into the capsules. Some plants will have both male and female flowers in such case only a single plant is required to produce capsules. Other plants will have either male or female flowers so that at least one male plant is required for the female plants to produce capsules.

Fruits: The fruit of *Dodonaea viscosa* is a winged capsule containing several small, round, black seeds. Capsule colour ranges from straw coloured to brown, pink to slight red to reddish-purple. Capsules are generally 2 to 4 winged.

Seed: Seeds are embedded in a capsule having round shape and blackish in colour. Each seed is about 1/8 inch in diameter. Seeds are extracted from the dry papery capsules and air dry at room temperature.

Storage: Store seeds in an airtight container with a desiccant. Keep them in a cool place with about 25 per cent relative humidity.

Soil requirement: The plant can grow in dry, sandy, stony or rocky soils. It thrives well on well-drained soils. It favours areas that receive full sun light and mostly absent in depressions.

Chemical Constituents:

The plant *Dodonaea viscosa*, contained alkaloids, flavonoids, fixed oil and fat, steroids, phenolics, saponins, tannins, gums, mucillages, carbohydrates, reducing sugar, glycosides and trace elements. The pharmacological studies showed that *Dodonaea* possessed antimicrobial, antidiabetic, insecticidal, antioxidant, cytotoxic, antifertility, wound, anti-inflammatory, analgesic, anti-ulcer, antispasmodic, antidiarrheal and detoxification effects.

Medicinal uses:

The literature showed that the plant can be used in the treatment of rheumatism, skin infections, diarrhoeas, stomachache, pains of hepatic or splenic origin, uterine colic and other disorders involving smooth muscles, antipruritic in skin rashes, dermatitis, haemorrhoids and sore throat. The infusions of leaves were used to treat rheumatism, gout, haemorrhoids, fractures and snake bites.

Underutilization of the shrub for Medicinal Purposes:

Despite of its lot of medicinal uses, even this shrub is not locally used for any of the health problem treatment in Himachal Pradesh. Mainly the shrub is used for stacking of vegetables and fuel-wood purposes being an excellent fuel-wood. The leaves along with twigs are used for animal bedding during the monsoon season. As the area under vegetable crops is increased in rural areas of the state, this shrub is mostly removed for stacking thereby reducing its regeneration. The shrub is not even planted by the forest department or any other organizations as more emphasis on tree plantation is given. The shrub is naturally regenerated through seeds. If the same pace of cutting the shrub continued in the lower parts of the state, then



it is very difficult to regenerate it and a time will come when it will be seen in the photographs only. To harvest its medicinal uses, the rural folk must be educated, trained and awaked about the importance and conservation of this important shrub.

Step forward to popularise the uses:

For encouraging and creating the awareness among the local masses regarding the uses and conservation of this shrub, awareness camps, group discussions and radio talks must be organised by the concerned agencies like State forest department, Research institutions, other line departments of the state, NGOs etc.. The Panchayati Raj Institutions, Self Help Groups, Farmer Societies, Village Forests Committees, Yuvak Mandal, Mahila Mandal and other community based organizations must be educated about the importance and uses of this shrub. This type of approaches certainly gear up the sustainable use and conservation of this shrub in its natural zone in the present perspective of changing climate.

ECHINODERMS: THE SPINE OF THE SEAFLOOR

Article ID: AG-VO5-I06-10***Kajal Rathod, Monali Kokate and Mohini Bhingare**

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Abstract

Echinoderms sea stars, sea cucumbers, sea urchins, and their relatives are sometimes disregarded in the marine environment, despite their critical role in maintaining our oceans healthy. These ancient animals silently impact the marine ecosystems, recycling nutrients in seabeds and regulating algae development on coral reefs. Their evolutionary success complements its ecological worth, as evidenced by a lineage back over around 500 million years. They also have an unbreakable connection to human existence, both economically as a food supply and culturally through coastal customs. However, climate change, ocean acidification, and overfishing pose threats to their existence. Echinoderms, act as sentinels and stewards of the water, demand greater attention and preservation. Understanding their role is more than simply a scientific undertaking; it is a step toward maintaining the balance of marine life.

Keywords: Echinoderms, climate change, biodiversity, conservation

What Are Echinoderms?

Echinoderms (phylum Echinodermata) are exclusively marine animals distinguished by radial symmetry, calcareous endoskeletons, and a distinct aqueous circulatory system. This hydraulic system fuels their mobility, feeding, and respiration, allowing them to perform duties that appear to be alien to land-dwelling organisms. Adults normally exhibit pentaradial symmetry, but their larvae are bilaterally symmetrical, indicating their evolutionary link to other deuterostomes, including chordates (Amemiya et al., 2005)

This phylum includes five main classes:



- **Asteroidea** (sea stars)
- **Echinoidea** (sea urchins and sand dollars)
- **Ophiuroidea** (brittle stars)
- **Holothuroidea** (sea cucumbers)
- **Crinoidea** (feather stars and sea lilies)

Their forms may differ dramatically, but all echinoderms share a similar internal architecture and physiology a unifying design that has proven evolutionarily successful for over 500 million years.

Ancient Origins, Resilient Survivors

Echinoderms have one of the most extensive and continuous fossil records among marine invertebrates. Their calcareous skeletons fossilise readily, allowing palaeontologists to trace their origins back to the Cambrian Explosion, a period of tremendous evolutionary experimentation in the waters (Foote, 1996). They survived many great extinctions, notably the end-Permian catastrophe, which killed over 90% of marine life. The flexibility is demonstrated by their colonisation of a wide range of marine settings, including tropical coral reefs and the deep oceans. Some crinoids and holothurians live in abyssal zones over 6,000 meters deep, hence echinoderms are a crucial group in researching the ecology and evolution of deep-sea life (Smith & Stockley, 2005).

Ecological Roles and Ecosystem Services

Echinoderms function as both engineers and regulators in marine ecosystems. Their influence extends from sediment turnover to population management of other marine creatures. Few roles are as follows:

1. Sediment Bioturbation and Nutrient Cycling

Sea cucumbers (Holothuroidea) are commonly known as the "vacuum cleaners of the sea." They consume vast volumes of silt, digest the organic content, and excrete cleaner sand, much like earthworms do in soil (Purcell et al., 2016). This method promotes nutrient cycling, increases microbial activity, and minimises organic accumulation, which can lead to hypoxia.

2. Algal Grazing and Reef Health

Sea urchins like *Diadema antillarum* are important grazers on coral reefs, suppressing algae development and allowing coral polyps to flourish. However, when their populations fall owing to disease or overharvesting, reefs can quickly transition to algae-dominated systems, resulting in ecological collapse (Ling et al. 2009). Their position as keystone grazers is critical for reef resiliency.

3. Predation and Population Control

Certain sea stars, such as *Pisaster ochraceus*, perform top-down control over bivalve populations in intertidal zones. In a famous ecological experiment, eliminating *Pisaster* resulted in a significant decrease in biodiversity due to unrestrained mussel growth, indicating how echinoderms influence community structure (Paine, 1969).

Echinoderms and Humans: An Economic and Cultural Connection

Though less popular than dolphins or sea turtles, echinoderms are economically important. Many coastal regions, mostly in the Indo-Pacific, gather sea cucumbers for food, medicine, and trade.

1. The Sea Cucumber Trade

Holothuria scabra and *Thelenota ananas* are highly valued in traditional Chinese medicine and food. These animals, processed and dried as "beche-de-mer" or "trepang," command high prices in Asian marketplaces. Unfortunately, increased demand has resulted in overexploitation, frequently with insufficient oversight or sustainable harvesting methods (Purcell et al., 2016).

2. Biomedical Potential

Echinoderms produce distinct bioactive chemicals, such as saponins, peptides, and steroids, which show promise in anticancer, antibacterial, and anti-inflammatory studies. Their regenerative properties have piqued attention in domains ranging from tissue engineering to regenerative medicine (Candia Carnevali, 2006).

Environmental Threats

Despite their resilience through geological time, echinoderms face growing challenges due to human activity:

1. Ocean Acidification

As many echinoderms rely on calcium carbonate to form their endoskeletons, ocean acidification is a severe concern. Lower pH levels damage skeleton formation in larval stages, reducing development and survival (Dupont et al., 2010).

2. Climate Change and Habitat Loss

Warming seas can alter reproductive cycles and larval dispersal patterns. Furthermore, coral reef destruction, bottom trawling, and pollution continue to deplete their habitats. Certain species are undergoing population reductions, while others, such as the crown-of-thorns starfish (*Acanthaster planci*), are thriving owing to ecological imbalance, resulting in significant coral degradation on the Great Barrier Reef (Pratchett et al. 2009).

Conservation and Sustainable Use

The ecological and economic value of echinoderms, scientists and policymakers are advocating for better management strategies:

- **Marine Protected Areas (MPAs):** These can safeguard echinoderm habitats, particularly in spawning and nursery grounds.
- **Aquaculture:** Pilot projects in countries like Vietnam and the Philippines are exploring sea cucumber farming as a sustainable alternative to wild harvest.
- **Fisheries Regulation:** Seasonal bans, size limits, and community-based management are being tested to restore overfished populations.

Education also plays a key role. Raising awareness about the value of echinoderms can foster a sense of stewardship among coastal communities and consumers alike.

Conclusion

Echinoderms may not be spectacular, but they are essential. As ecological architects, nutrient cyclers, predators, and prey, they weave the aquatic world together in subtle and deep ways. From their ancient evolutionary history to their current economic significance, they demonstrate that even the quietest species can leave the greatest footprints or, in this case, star-shaped impressions on the seafloor. Protecting echinoderms is about more than just maintaining

biodiversity; it's about ensuring the whole health and balance of the ocean system for fishers, reef builders, and future generations.

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FROM SOIL TO TABLE: THE BENEFITS OF NATURAL FARMING

Article ID: AG-VO5-I06-11***R. Rebecca¹, S.U. Vikraman² and K. Suriya³**

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Abstract

Natural farming is a sustainable, chemical-free agricultural system rooted in traditional Indian practices and modern ecological principles. It integrates crops, trees, and livestock to promote biodiversity, improve soil health, conserve water, and reduce environmental impact. By eliminating synthetic inputs and using locally sourced microbial formulations, natural farming enhances ecosystem resilience while lowering production costs and increasing farmer incomes. Government initiatives like the National Mission on Natural Farming and Paramparagat Krishi Vikas Yojana support its widespread adoption across India. Despite challenges such as yield variability, natural farming offers a promising path toward climate-resilient, environmentally friendly agriculture. Continued innovation, collaboration, and policy support are essential to scaling its benefits and ensuring global food security through sustainable practices.

Key words: Natural farming; soil health; sustainability; Conservation and biodiversity

Introduction

Natural Farming is a chemical-free, sustainable farming system rooted in traditional Indian practices and enriched by modern ecological principles. It follows an agroecology-based, diversified approach that integrates crops, trees, and livestock to promote functional biodiversity. This method emphasizes the recycling of on-farm biomass, particularly through mulching, the use of cow dung and urine-based formulations, and the exclusion of synthetic chemical inputs. Natural farming maintains soil health through proper aeration and resource optimization,

reducing reliance on external inputs. It is recognized as a cost-effective practice with significant potential to boost employment and support rural development.

Current Developments in Natural Farming in India

Several Indian states have actively initiated programs to promote natural farming. Andhra Pradesh, Gujarat, Himachal Pradesh, Odisha, Madhya Pradesh, Rajasthan, Uttar Pradesh, and Tamil Nadu are among the frontrunners in adopting and expanding this practice. Currently, over 1 million hectares of land across India are under natural farming, reflecting its growing acceptance and implementation among farmers.

Aims and Objectives of Promoting Natural Farming

The promotion of natural farming focuses on preserving the natural flora and fauna while restoring soil health, fertility, and its biological activity. It aims to maintain crop diversity and ensure the efficient use of land and natural resources such as sunlight, air, and water. Natural farming encourages the presence of beneficial insects, animals, and soil microbes to support nutrient recycling and provide natural pest and disease control. It also emphasizes the use of natural, locally available inputs and the integration of indigenous livestock breeds. By reducing input costs and enhancing resource efficiency, natural farming seeks to improve the overall economic well-being of farmers.

Natural farming Practices

Natural farming aims to restore soil health, maintain biodiversity, ensure animal welfare, promote ecological balance, and encourage the efficient use of natural and local resources. It is an ecological farming approach that works in harmony with natural biodiversity supporting soil biological activity and managing the complex interactions among plants, animals, and microorganisms within the food production system.

Key practices essential for the adoption of natural farming include:

- Eliminating chemical inputs and using indigenous seeds to preserve genetic diversity. Farmers apply microbial formulations like Bijamrita for seed treatment and Jivamrita for enriching soil health.
- Cover cropping, mulching, and mixed cropping systems help recycle nutrients and support beneficial microbes.
- On-farm biodiversity is enhanced through tree integration and natural pest management using botanical preparations.

- Livestock integration, especially native breeds, along with water and moisture conservation, ensures a sustainable and resilient farming system.

Rising input costs, with fertilizer prices increasing by 60%-600% over the past decade, have significantly reduced farm incomes. Although crop yields have improved, the cost of production has outpaced gains, impacting farmers' profitability. Green Revolution technologies are now linked to agro-ecosystem degradation and declining soil health due to excessive chemical use. Natural farming offers a sustainable, low-cost alternative by using bio-inputs like Jeevamrit and practices like intercropping and mulching. Recognizing its potential, India's Economic Survey highlights natural farming as a key approach to boost farmer incomes sustainably.

Sustainable agriculture can be achieved by following key principles such as adopting diversified cropping systems to enhance resilience and productivity, recycling naturally available nutrients within the field to maintain soil health, and utilizing on-farm generated biomass to reduce dependency on external inputs. It also involves the use of locally developed and refined practices based on plant, animal, and microbial resources, tailored to the specific agro-ecological conditions. Furthermore, continuous innovation by farmers plays a vital role, as they adapt and evolve practices based on local cropping patterns, climatic conditions, altitude, soil quality, and pest variability to ensure sustainable and effective farming solutions.

Scope of Natural Farming

There are many working models of natural farming all over the world, the zero budget natural farming (ZBNF) is the most popular model in India. Natural Farming improves soil fertility, environmental health as well as helps in the reduction of greenhouse gas emissions and also promises the enhancement of farmer's income. In broad terms, Natural Farming can be considered as a prominent strategy to save the planet Earth for future generations. It has the potential to manage the various farmland practices and hence sequester the atmospheric carbon in the soils and plants, to make it available for plants.

Benefits of Natural Farming

Improve Yield Farmers practicing Natural Farming reported similar yields to those following conventional farming. In several cases, higher yields per harvest were also reported.



Ensures Better Health: As Natural Farming does not use any synthetic chemicals, health risks and hazards are eliminated. The food has higher nutrition density and therefore offers better health benefits.

Environment Conservation: Natural Farming ensures better soil biology, improved agrobiodiversity and a more judicious usage of water with much smaller carbon and nitrogen footprints.

Increased Farmers Income: Natural Farming aims to make farming viable and aspirational by increasing net incomes of farmers on account of cost reduction, reduced risks, similar yields, incomes from intercropping.

Employment Generation

Natural farming generates employment on account of natural farming input enterprises, value addition, marketing in local areas, etc. The surplus from natural farming is invested in the village itself.

Reduced Water Consumption: By working with diverse crops that help each other and cover the soil to prevent unnecessary water loss through evaporation, Natural Farming optimizes the amount of ‘crop per drop’.

Minimized Cost of Production: Natural Farming aims to drastically cut down production costs by encouraging farmers to prepare essential biological inputs using on-farm, natural and homegrown resources.



Natural Farming: A Step Towards Brewing a Greener Future

Natural farming, rooted in agroecology and traditional practices, offers a chemical-free, ecological approach that harmonizes with nature. It integrates crops, trees, and livestock to enhance soil fertility, conserve water, and reduce environmental impact. By prioritizing biodiversity, natural farming fosters long-term sustainability and ecosystem resilience.

The Government of India, has been promoting natural farming, in a bid to empower and bring about more social and economic stability for the farmers. This practice of using locally available resources based on traditional knowledge, makes it a sustainable and viable option. The government has introduced several initiatives to promote natural farming such as:

The National Mission on Natural Farming (NMNF), launched in 2023-24, promotes chemical-free farming with financial support of ₹15,000 per hectare per year for three years.

Paramparagat Krishi Vikas Yojana (PKVY), started in 2015, focuses on improving soil health under the National Mission on Sustainable Agriculture.

Bharatiya Prakritik Krishi Paddhati (BPKP), a sub-scheme of PKVY launched in 2019, supports indigenous Zero Budget Natural Farming with ₹12,200 per hectare for three years. BPKP aims to cover 12 lakh hectares across 600 major blocks by 2024-25 through cluster formation, training, and certification.

The National Centre for Organic and Natural Farming (NCONF) promotes natural and organic farming and acts as a knowledge hub for bio-fertilizers. India plans to support one crore farmers in transitioning to natural farming with certification and branding over the next two years. Finance Minister Nirmala Sitharaman allocated ₹1.52 lakh crore to agriculture in the 2024 budget, reinforcing the government's commitment.

Core principles driving natural farming

A balanced and sustainable agricultural system is central to natural farming and is guided by the following principles:

- ✿ Minimal soil disturbance
- ✿ Improvement of soil fertility and health
- ✿ Promotion of biodiversity
- ✿ Focusing on Soil Health
- ✿ Adopting natural pest management practices
- ✿ Conserving water
- ✿ Local adaptation for optimizing growth and sustainability
- ✿ Reducing dependency on external inputs

Environmental and Climate Impact

Natural farming supports the environment by enhancing soil fertility, reducing greenhouse gas emissions, and minimizing water pollution through the avoidance of synthetic inputs. It promotes biodiversity and ecosystem resilience by encouraging diverse plant and animal life, attracting pollinators, and preserving natural habitats. Practices like composting, mulching, and reduced tillage boost carbon sequestration, improve water efficiency, and create climate-resilient crops and soils. By recycling organic waste and reducing reliance on external inputs, natural farming lowers carbon and nitrogen footprints, contributing to a healthier climate.



Industry Perspective and Future Outlook

While natural farming offers many benefits, it also poses risks, as seen in Andhra Pradesh where yields of wheat and basmati rice declined significantly under ZBNF. There are concerns about its ability to meet the food demands of a growing population like India's. A successful transition requires strong collaboration among consumers, policymakers, researchers, and industry leaders. Supportive policies and global partnerships will be key to expanding natural farming and tapping into international markets.

Conclusion

Natural farming holds great potential to address global food security while preserving biodiversity. It supports environmental sustainability through soil health, water conservation, and reduced emissions. With its holistic and climate-resilient approach, it leads the way in sustainable agriculture. On going innovation and strategic partnerships are key to its continued growth and impact. Natural farming is poised to be a transformative force in building a resilient agricultural future.

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EFFECT OF ELEVATED CO₂ IN GREENHOUSES

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Abstract

In the protected cultivation, the plant micro climate can be easily manipulated to get higher yield, on such parameter is CO₂ concentration. The elevated carbon dioxide has various effect on the plant physiology. Apart from increasing the photosynthesis rate, it increases the water use efficiency by reducing the transpiration rate. Transpiration is reduced by the partial closure of stomata. It also alters the nutrient concentration in plant tissues. At elevated carbon dioxide the nitrogen concentration is diluted, protein content is decreased. The effect varies from crop to crop. C₃ plants respond more than C₄ plants due to the lower internal concentration in C₃ plants. The optimum level of CO₂ in greenhouse is 1000-1300 for most crops. Higher concentration may also cause toxic effect to some species. Overall, by manipulating the concentration of carbon dioxide in protected structures within the desirable level we can get better yield and increased water use efficiency.

Introduction

India is a country with vast agro-climatic zones in it, which helps us to grow wide range of crops from tropical to temperate crops. But due to the climatic changes, soil degradation, water scarcity, and other causes result in reduction in productivity. We also have to increase the productivity to meet the drastic increase in the population. To overcome these problems protected structures can be used. Protected structures are widely used nowadays to grow wide range of

crops because of their controlled environment where we can manipulate various parameters so that we can achieve greater yield. In that we can control the microclimate of the crops by manipulating various parameters such as temperature, light intensity, humidity and gas concentration especially carbon dioxide and oxygen. Since carbon dioxide plays a major role in carbon assimilation in plants and directly correlated with the photosynthesis rate in crops. Elevating the carbon dioxide have a great effect in greenhouse cultivation which has been discussed over years. In this article we will be discuss on the physiological change in plants to elevated CO₂.

EFFECT OF ELEVATED CARBON DIOXIDE IN CROP GROWTH :

Carbon dioxide is essential for the photosynthesis process where the light energy is used to convert carbon dioxide and water into sugars and oxygen. Increasing the carbon dioxide level in the greenhouse increase the dry matter accumulation by increasing the photosynthesis rate. It also causes early flowering, higher fruits yield, increasing flower size, improving stem strength and reduce bud abortion in flowers.

For majority of crops, the level of carbon dioxide concentration used is 340-1000 ppm. Most crops show increase in the photosynthetic rate by 50% at 1000ppm compared to the ambient carbon dioxide levels in greenhouse. But not all crops have equal effect. Light is also required to increase the photosynthetic rate. So, giving elevated CO₂ with low light has no greater effect.

The crops like tulips, eastern lilies has no response to increase in carbon dioxide levels. For crops like African violets and some gerbera varieties increase in carbon dioxide over 1000ppm cause brittleness in flowers so the concentration of 500-800 ppm is advisable for them. For crops like tomato and lettuce the concentration of 800-1000 ppm is advisable. For majority of crops the concentration of 1000-1300ppm is required for higher yield in greenhouse.

EFFECT ON WATER USE EFFICIENCY

Elevated on carbon dioxide increases the water use efficiency in crops by reducing the transpiration rate in the plants. Water use efficiency (WUE) is an important parameter which is the dry matter produced by the plants per unit of water applied for production. The increase in carbon level in both above and below ground part of the plants leads to partially closure of the stomata. Stomata is the site through which transpiration and gas exchanges occur. If the stomata is partially closed the aperture of stomata is reduced leading to lower stomatal conductance.

When the concentration of CO₂ increases the beta carbonic anhydrase 1 (CA1) and beta

carbonic anhydrase 4 (CA4) gets activated it converts the carbon dioxide into bicarbonate in the plant tissues. The high amount of bicarbonate activation anion channels which causes release of anions from the guard cells of stomata leading to the depolarization of the membrane of guard cells. These reaction results in the leaving of water from the guard cells makes it flaccid. Hence causes the partial closure of stomata. 0.1 increase in WUE cause increase in yield by 0.3 tons.

EFFECT ON NITROGEN CONTENT:

The increase in atmospheric CO₂ results is dilution in the concentration of nitrogen in the plant tissues. Even the exact reason behind this is unknown, there are many hypothesis that explain the statement. The increase in the CO₂ causes more increase in carbohydrates due to higher production of the photosynthesis rate. Even the carbohydrate is increasing the nitrogen uptake is the same, it does not keep up with the increase in photosynthesis. Hence the nitrogen is diluted in the tissue.

The effect on enzymes that is responsible for nitrogen assimilation can also leads to reduce in nitrogen concentration in plants. Enzymes like nitrate reductase are reduced when the CO₂ is higher hence is reduced the nitrate conversion that is even when enough nitrogen is present the conversion of the organic form in inorganic will be slowed down. The higher CO₂ in the rhizosphere can affect the microbe population in the rhizosphere, there may be an effect on the nitrogen fixing bacteria.

An indirect effect is the increase in CO₂ causes decrease in the stomatal conductance which reduces the transpiration. Even great amount of water is loss by transpiration, transpiration is responsible for water uptake greatly. Thus, reduced transpiration reduces the water uptake so the minerals absorbed along the water is also reduced. Reduced in the nitrogen concentration causes reduced in protein content in plants.

EFFECT IN DIFFERENT PLANTS :

The effect varies with the crop species mostly. The C₃ plants like tomato, brinjal show more response to the elevated carbon dioxide compared to the C₄ plants like Amaranthus. The C₃ plants shows 30-40% increase in yield whereas in the C₄ plants it is only observed lower that is 10-15% increase in yield (Hamim *et al.*,2005).

The difference is due to the difference in the CO₂ concentration inside the plant tissue that is C_i. the gases enter into the plants by diffusion process that is from higher concentration to

the lower concentration. So more the lower concentration inside the plants more the carbon dioxide enters into the plants.

The C_i in C_3 is lower when compared to C_4 plants because in the C_4 plants the carbon dioxide is pumped by CO_2 pump from mesophyll cells into the bundle sheath. The Rubisco enzymes are present in the bundle sheaths. The carbon dioxide is concentrated inside the bundle sheath hence the internal concentration of the C_4 is always higher. Moreover, since the rubisco enzymes present near the CO_2 the photorespiration is greatly reduced.

APPLICATION OF THE CO_2 IN GREENHOUSES:

The Carbon dioxide is supplied by various ways such as burning of fuels that are carbon based. Some examples are natural gas, propane and kerosene. These fuels by burning not only produce carbon dioxide but also produce heat energy which can be utilized inside a greenhouse in winter conditions. But the disadvantage in it is the carbon dioxide is not pure. It also have some highly toxic gases which can affect the crop growth. Mainly the fuels which are used in greenhouse should not have Sulphur level more than 0.02% by weight. The burning of fuels also produce moisture,

1.4 kg of water vapor is generated by each m^3 natural gas burned.

If no suitable fuel is available, we can go with supplementing pure CO_2 in the form of liquid CO_2 . It does not produce any toxic gases or heat. So, in summer when burning fuels add more temperature increase, liquid sources can be supplied. It is applied through irrigation lines especially in drip irrigation mixed with water. But the cost of the liquid CO_2 is higher that is above 2000 per liter.

TOXIC EFFECT OF CO_2 :

Even though it has positive effect, the prolonged elevated conditions for long terms can also have some negative effects. If the carbon dioxide level is more than 5000ppm for long time it may cause increase in the temperature at certain point it may be harmful to the plants especially in the protected structures, since it is a closed environment. It also cause negative effect to the humans also when consumed for long period. The plants also have low nutrient content.

Conclusion

When we are adapting for protected structures for cultivation, the cost of establishment is higher. So, in order to get maximum profit, we should manipulate the environment to

maximum for much benefit. Adjusting the CO₂ concentration inside the greenhouse is one of the ways to improve the yield. The increase in carbon dioxide increase the yield by 15-20% which results in higher profits. But even though it has positive effect the level should be maintain at optimum so it does not have any negative effect to plant such as high temperature. Mostly for all crops the concentration of 1000 -1500 ppm found beneficial. Apart from increasing the carbon assimilation in plants, it also increase the water use efficiency (WUE) so that the plants transpiration rate is reduced due to partial closure of stomata. But the nutrient content is reduced in the plants especially the nitrogen content is diluted due to various factors. So, the elevated carbon dioxide has various effects in plants but it is all about how we manage them to get the results we want.

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ROLE OF INTEGRATED FARMING SYSTEM IN NATURAL FARMING: A PATHWAY TO NEW ERA OF AGRICULTURE

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Introduction

Agriculture is currently facing significant challenges, including deteriorating soil health, overreliance on chemical inputs, loss of biodiversity, and increasing climate variability. In this context, ensuring food security while conserving natural resources demands a sustainable and environmentally sound approach. Natural farming, which emphasizes ecological harmony and minimizes external inputs, offers a promising alternative to conventional practices. Complementing this, the Integrated Farming System (IFS) provides a comprehensive model that enhances the productivity, resilience, and economic sustainability of natural farming by integrating diverse agricultural components within a single farming unit.

What is Natural Farming?

According to the Ministry of Agriculture & Farmers Welfare, Government of India, Natural Farming is: "A chemical-free farming system based on traditional Indian practices, focusing on the use of on-farm biomass and natural inputs for soil enrichment and plant protection. It promotes the principles of agroecology and sustainability by eliminating the use of synthetic fertilizers and pesticides." It emphasizes use of natural inputs like jeevamrit, beejamrit, ghana jeevamrit, and mulching, along with crop rotation, cover cropping, and biodiversity enhancement.

Key Features of Natural Farming:

1. **No synthetic inputs** – Prohibits chemical fertilizers and pesticides.
2. **On-farm inputs only** – Emphasizes preparations like *Jeevamrit*, *Beejamrit*, *Ghana Jeevamrit*, and *cow-based inputs*.
3. **Soil health first** – Focus on improving soil fertility through microbial activity and organic matter.
4. **Low-cost farming** – Reduces input costs significantly; promoted as a "zero-budget" practice.
5. **Agroecological foundation** – Encourages biodiversity, crop rotation, mulching, and natural pest control.

What is Integrated Farming System (IFS)?

The Integrated Farming System is a diversified and holistic farming approach that integrates multiple components — such as crops, livestock, fishery, poultry, mushroom cultivation, agroforestry, and vermicomposting — on a single farm unit. This integration helps maximize resource use efficiency and productivity per unit area, especially for small and marginal farmers.

Role of IFS in Natural Farming Enhances Nutrient Recycling

IFS complements natural farming by promoting internal nutrient cycling. Animal dung and urine from cattle, poultry droppings, and crop residues become valuable raw materials for composting or preparing natural inputs like *jeevamrit*. This reduces dependency on external fertilizers, aligning with natural farming goals.

Promotes Biodiversity

By integrating crops with livestock, fisheries, and trees, IFS fosters agrobiodiversity, which plays a key role in pest control, soil fertility restoration, and climate resilience — all central to the philosophy of natural farming.

Reduces Input Costs

IFS ensures that natural inputs are generated within the farm. This reduces cost of cultivation significantly, which is one of the core objectives of natural farming.

Enhances Income and Employment

Natural farming sometimes faces criticism for lower initial yields during the transition period. However, IFS fills this economic gap by offering multiple income sources — such as milk, eggs, fish, or vegetables — ensuring year-round livelihood security and reducing risk.

Efficient Resource Utilization

Water, labor, and organic matter are better utilized in IFS. For instance, wastewater from fishponds can be used for irrigation; crop residues feed livestock; animal dung feeds vermicompost pits — making it a zero-waste, self-reliant system in line with natural farming values.

Climate Change Mitigation and Resilience

The diversity of components in IFS — such as trees, livestock, and perennial crops — acts as a natural buffer against climatic shocks, improving the farm's ecological resilience. It also contributes to carbon sequestration and reduction of greenhouse gas emissions.

Case Example: Makhana + Fish + Vegetable + Poultry Model in Bihar

In the flood-prone Koshi region of Bihar, farmers practicing natural farming have successfully adopted IFS models integrating makhana, fishery, vegetables, and backyard poultry. These systems have led to:

- 30–40% increase in net income
- Reduction in pest incidence
- Enhanced soil organic carbon
- Employment for family labor throughout the year

Policy and Institutional Support Needed

To promote the synergy between IFS and natural farming, the following support mechanisms are crucial:

- Training and demonstration under schemes like Bharatiya Prakritik Krishi Paddhati (BPKP)
- Credit and input support for diversification
- Custom hiring centers for natural input preparation
- Market linkage for IFS produce (organic certification, branding)

Conclusion

The integration of IFS with natural farming is not merely an option but a necessity for sustainable, resilient, and profitable agriculture. Together, they address environmental concerns,



reduce external dependency, and empower farmers especially smallholders by transforming farms into self-sufficient ecosystems. It is time to rethink agriculture as an integrated ecological enterprise rather than a mono-crop factory.

IMAGE ANALYSIS: A SMART TOOL FOR PRECISION PLANT PATHOLOGY

Article ID: AG-VO5-I06-14***Sanjeev Kumar**

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Introduction

Plant diseases pose a significant threat to global agriculture, impacting crop productivity, quality, and ultimately food security. Traditional methods for disease detection, such as visual inspection and laboratory analysis, are often time-consuming, costly, and sometimes unreliable due to their dependence on expert knowledge and destructive sampling. In response to these challenges, image analysis—particularly through digital imaging and advanced computational techniques—has emerged as a powerful, non-destructive, and cost-effective approach for the rapid detection and management of plant diseases. By leveraging image processing and machine learning, this technology enables early and precise identification of diseases, offering new possibilities for sustainable agriculture and improved crop management.

Role of Image Analysis in Plant Disease Detection

Image analysis plays a critical role in the detection and management of plant diseases by automating the identification process and providing objective, reproducible results. The main contributions include:

- **Early Detection:** Image analysis can identify disease symptoms at an early stage, often before they become visible to the naked eye, allowing for timely intervention and reduced crop loss.
- **Non-Destructive Diagnosis:** Unlike traditional methods, image-based techniques do not require damaging plant tissues, preserving samples for further study or continued growth.

- **Scalability:** Automated systems can process large numbers of samples quickly, enabling field-wide or even regional disease surveillance.
- **Objective Assessment:** Reduces human error and subjectivity, providing consistent and accurate disease identification.

Uses of Image Analysis in Plant Disease Management

- **Disease Surveillance:** Monitoring the spread and severity of diseases across large agricultural areas using drones, satellites, or stationary cameras.
- **Precision Agriculture:** Targeted application of pesticides or other interventions based on localized disease detection, reducing chemical use and environmental impact.
- **Research and Breeding:** Supporting plant phenotyping for disease resistance studies and breeding programs by quantifying disease symptoms objectively.
- **Mobile Diagnostics:** Empowering farmers with smartphone-based applications for real-time disease diagnosis in the field.

Methods and Techniques

1. Image Acquisition

- **Devices:** Digital cameras, smartphones, RGB sensors, multispectral and hyperspectral cameras are commonly used to capture images of plant leaves, stems, or fruits.
- **Conditions:** Proper lighting and background control are essential to ensure image quality and reliability.

2. Image Pre-processing

- **Noise Reduction:** Removing background interference and normalizing lighting conditions to enhance image quality.
- **Filtering and Enhancement:** Techniques such as histogram equalization and color correction improve the visibility of disease symptoms.

3. Image Segmentation

- **Purpose:** Separates the region of interest (e.g., diseased leaf area) from the background to focus analysis on relevant plant tissues.
- **Techniques:** Thresholding, edge detection, and clustering algorithms are commonly employed.

4. Feature Extraction

- **Visual Features:** Extracts characteristics such as color, texture, shape, and size, which are indicative of specific diseases.
- **Common Descriptors:** Colour histograms, Gabor filters, wavelet transforms, and shape descriptors help differentiate between healthy and diseased tissues.

5. Classification and Detection

- **Machine Learning Models:** Algorithms like Support Vector Machines (SVM), k-Nearest Neighbours (K-NN), Artificial Neural Networks (ANN), and especially Convolutional Neural Networks (CNNs) are used for disease classification.
- **Deep Learning:** CNNs have achieved high accuracy in classifying multiple diseases across various crops, as demonstrated by models trained on large datasets such as Plant Village, achieving up to 99.35% accuracy.
- **Training:** Models are trained on labelled datasets of healthy and diseased plant images, enabling automated classification of new samples.

6. Disease Diagnosis and Management

- **Reporting:** The system generates a diagnosis report, specifying the disease type, severity, and recommended management strategies.
- **Decision Support:** Enables informed decision-making for interventions such as pesticide application, crop rotation, or pruning. ★ ★ ★ ★

Applications

- **Automated Field Monitoring:** Real-time surveillance of crops for early disease detection using stationary or drone-mounted cameras.
- **Mobile Apps for Farmers:** Smartphone-based diagnostic tools that analyse leaf images and provide instant feedback.
- **Research Platforms:** High-throughput phenotyping systems for evaluating disease resistance in breeding programs.
- **Precision Treatment:** Site-specific management of diseases, optimizing resource use and minimizing environmental impact.

Advantages

- **Efficiency:** Rapid screening of large plant populations, reducing labor and time requirements.

- **Cost-Effectiveness:** Minimizes the need for expensive laboratory tests and expert labour.
- **Accuracy:** High precision in disease detection and classification, reducing false positives and negatives.
- **Sustainability:** Supports reduced chemical usage and promotes environmentally friendly agricultural practices.

Challenges

- **Environmental Variability:** Changes in lighting, background, and plant appearance can affect analysis accuracy.
- **Data Requirements:** High-quality, annotated image datasets are essential for effective model training and validation.
- **Generalization:** Models trained on specific crops or conditions may not perform well in different environments or on new diseases.

Conclusion

The integration of image analysis into plant disease management represents a significant advancement in agricultural technology. By enabling early, accurate, and scalable disease detection, image processing and machine learning techniques support sustainable farming, improve crop yields, and enhance food security. As technology and datasets continue to evolve, image-based plant disease management systems will become even more precise, accessible, and impactful for farmers and researchers worldwide.



DARK OXYGEN: THE INVISIBLE BREATH OF OCEANS

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Abstract

In a ground-breaking marine discovery, scientists have reported the production of oxygen in the deepest, darkest regions of the ocean — places completely devoid of sunlight. This phenomenon has been termed “dark oxygen” because it occurs in zones where traditional photosynthesis is impossible due to the absence of light. This revelation challenges the long-standing assumption that all oxygen in oceans is produced by sun-driven photosynthetic organisms like algae and phytoplankton. The presence of oxygen in these sunless zones indicates the existence of previously unknown chemical processes or ecosystems thriving in extreme conditions.

Introduction

For decades, science believed that oxygen – the life-giving gas that sustains much of life on Earth – could only be produced in the presence of light, mainly through photosynthesis by plants, algae, and plankton. These microscopic marine organisms, bathed in sunlight near the ocean’s surface, were thought to be the sole oxygen factories of the sea. But a mysterious new discovery is challenging that assumption.

Scientists have found oxygen being formed thousands of feet below the ocean’s surface, in total darkness – far beyond the reach of sunlight and seemingly without any involvement of photosynthesis. This phenomenon, now referred to as “Dark Oxygen”, suggests that molecular oxygen (O₂) can be generated through non-photosynthetic processes, even in deep, dark, and anoxic marine environments. One controversial explanation points to the polymetallic nodules lying on the ocean floor. These coal-like lumps, rich in metals like manganese, cobalt, and

nickel, are believed to produce oxygen through electrochemical reactions by splitting water molecules (H_2O) – without needing sunlight.

This ground-breaking insight could transform how we understand marine ecosystems, oxygen cycling, and even life on other planets. However, not all scientists agree on the mechanism, and debates around the metallic nodule theory continue. Still, dark oxygen production opens a fascinating new chapter in ocean science – one that dives deeper into the ocean's most hidden secrets and forces us to rethink how life might be sustained in places once considered impossible.

Where Was It Discovered?

The phenomenon was observed in the Clarion-Clipperton Zone (CCZ), located in the Pacific Ocean off the western coast of Mexico. This area is especially significant because it holds the world's largest concentration of polymetallic nodules, making it an ideal natural laboratory for studying such mysterious deep-sea processes.

The CCZ is already a target zone for commercial deep-sea mining, which adds urgency to understanding the potential ecological impacts of disturbing this newly discovered oxygen-generating ecosystem.

How Is Dark Oxygen Possibly Produced?

One of the most intriguing hypotheses behind dark oxygen production centers around polymetallic nodules found on the ocean floor. These coal-like lumps are rich in metals such as manganese, iron, cobalt, nickel, copper, and lithium.

It is believed that these nodules might act like tiny natural batteries, transporting electric charges that split water molecules (H_2O) into hydrogen and oxygen. This electrochemical water splitting does not require sunlight, making it a plausible source of oxygen in deep, dark environments. Still, the exact energy source driving this splitting remains unknown, and the theory is under scientific debate.

India's Role and Initiatives

India has long shown interest in deep-sea exploration. In 1987, India became the first Pioneer Investor to receive exclusive exploration rights in the Central Indian Ocean Basin (CIOB), covering 1.5 lakh sq. km. In 2024, India applied for further exploration, including areas like the Afanasy Nikitin Seamount, a cobalt-rich region.

The Ministry of Earth Sciences is actively developing a manned submersible under the Samudrayaan Mission to mine seabed resources. However, with the discovery of dark oxygen, India must also consider the environmental impact and adapt its ocean policy to balance resource extraction and marine conservation.

What Is Deep-Sea Mining, and Why Is It Linked to Dark Oxygen?

Deep-sea mining refers to the extraction of valuable mineral deposits from the ocean floor. There are three main forms:

1. Mining polymetallic nodules from sediment,
2. Extracting sulfide-rich hydrothermal vents, and
3. Harvesting cobalt crusts from underwater mountains.

These resources contain metals essential for the renewable energy industry, battery production, and modern electronics. However, since the same polymetallic nodules may be responsible for generating dark oxygen, mining activities could threaten these oxygen-dependent ecosystems. This raises major environmental concerns, as disrupting these regions might damage unknown species, affect global oxygen cycles, and introduce irreversible changes in marine biodiversity.



The black polymetallic sea nodules, the nickel, manganese and cobalt rich mineral deposits, these balls form naturally deep under the sea. [File: Pallava Bagla/Corbis via Getty Images]

Environmental Concerns and Ethical Implications

The discovery of dark oxygen has sparked growing ecological concern. Deep-sea ecosystems are poorly understood, and any disruption—especially removal of polymetallic nodules—could lead to oxygen depletion, harming organisms that may rely on this unexpected source of oxygen. Moreover, mud plumes and sediment disturbances from mining may interfere with the nutrient and reproductive cycles of delicate deep-sea species like jellyfish and benthic invertebrates. Without adequate scientific understanding of these ecosystems, deep-sea mining may do more harm than good, making environmental protection a pressing priority.

Scientific and Global Significance

This discovery has wide-reaching implications. It challenges fundamental assumptions about oxygen production on Earth, adds a new layer to our understanding of marine biogeochemistry, and opens the door to exploring life in other extreme environments — including on other planets or moons like Europa. If oxygen can be created without sunlight, it means life-supporting environments could exist even in dark, alien oceans. However, more research is required to verify the mechanism behind this process, and until then, any mining activity must proceed cautiously.





MICROGREENS- PICK TO PLATE FOR HEALTHY DIET

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Introduction

Microgreens are young vegetable greens that are approximately 1–3 inches (2.5–7.5 cm) tall. They have an aromatic flavor and concentrated nutrient content and come in a variety of colors and textures. Microgreens are considered baby plants, falling somewhere between a sprout and baby green. Micro greens shouldn't be confused with sprouts, which do not have leaves. Sprouts also have a much shorter growing cycle of 2–7 days, whereas microgreens are usually harvested 7–21 days after germination, once the plant's first true leaves have emerged. Microgreens are more similar to baby greens in that only their stems and leaves are considered edible. However, unlike baby greens, they are much smaller in size and can be sold before being harvested. This means that the plants can be bought whole and cut at home, keeping them alive until they are consumed.

Microgreens, are becoming more and more popular worldwide as fresh, ready-to-eat functional, and nutraceutical food. They have great potential to diversify and enhance the human diet and address nutrient deficiencies due to their high content of phytochemicals. Microgreens, also known as "vegetable confetti," are developed from various commercial food crops, such as vegetables, grains, and herbs, and consist of fully developed cotyledons with or without partially expanded true leaves. The exact portion of the emerging stem of the tender plant, along with the cotyledon leaves and the probable true leaves, are harvested 7–21 days after germination. These functional micro-vegetables are usually 2–8 cm in height and have intense sensory attributes, such as flavor, texture, aroma, appearance, and exotic colors, despite their small size. They are



also overloaded with an abundant level of various phytonutrients, which vary according to the nature of the plants chosen to produce the microgreens. Due to their high content of various health-promoting phytonutrients, such as antioxidants, vitamins, minerals, phenolic compounds, and other health-promoting compounds, they are considered the next generation of "superfoods" or "functional foods." They are also preferred as a source of raw foods by various vegans who are specific in consuming nutrient-enriched dietary food.

HISTORY

Microgreens began showing up on chefs' menus as early as the 1980s in San Francisco. In Southern California, microgreens have been grown since the mid-1990s. Initially, a few varieties were offered; those available were: arugula, basil, beets, kale, cilantro and a colorful mixture of those called a "Rainbow Mix". Having spread eastward from California, they are now being grown in most areas of the United States, with an increasing number of varieties. Today, the U.S. industry for microgreens consists of a variety of seed companies and growers.

Microgreens have three basic parts: a central stem, cotyledon leaf or leaves, and typically, the first pair of very young true leaves. They vary in size depending upon the specific variety grown, with the typical size being 1 to 1.5 in (25 to 38 mm) in total length. When the plant grows beyond this size, it is generally no longer considered a microgreen, instead being called a petite green. The average crop-time for fast-growing microgreens, such as many brassicas, is 10–14 days from [seeding](#) to harvest. Slower growing microgreens, such as beets, chard, and many herbs, may take 16–25 days to reach harvestable size. Both baby greens and microgreens lack any legal definition.

The terms "baby greens" and "microgreens" are marketing terms used to describe their respective categories. Sprouts are germinated seeds and are typically consumed as an entire plant (root, seed, and shoot), depending on the species. Sprouts from almond, pumpkin, and peanut reportedly have a better flavor when harvested prior to root developments. Sprouts are legally defined and have additional regulations concerning their production and marketing due to their relatively high risk of microbial contamination compared to other greens

Different Types of Microgreens

Microgreens can be grown from many different types of seeds. The most popular varieties are produced using seeds from the following plant families:

- **Brassicaceae family:** Cauliflower, broccoli, cabbage, watercress, radish and arugula

- **Asteraceae family:** Lettuce, endive, chicory and radicchio
- **Apiaceae family:** Dill, carrot, fennel and celery
- **Amaryllidaceae family:** Garlic, onion, leek
- **Amaranthaceae family:** Amaranth, quinoa swiss chard, beet and spinach
- **Cucurbitaceae family:** Melon, cucumber and squash

Cereals such as rice, oats, wheat, corn and barley, as well as legumes like chickpeas, beans and lentils, are also sometimes grown into microgreens. They vary in taste, which can range from neutral to spicy, slightly sour or even bitter, depending on the variety. Generally their flavor is considered strong and concentrated.

Microgreens Are Nutritious?

Microgreens are packed with nutrients. While their nutrient contents vary slightly, most varieties tend to be rich in potassium, iron, zinc, magnesium and copper. Microgreens are also a great source of beneficial plant compounds like antioxidants. What's more, their nutrient content is concentrated, which means that they often contain higher vitamin, mineral and antioxidant levels than the same quantity of mature greens.

Research comparing microgreens to more mature greens reports that nutrient levels in microgreens can be up to nine times higher than those found in mature greens. Research also shows that they contain a wider variety of polyphenols and other antioxidants than their mature counterparts. One study measured vitamin and antioxidant concentrations in 25 commercially available microgreens. These levels were then compared to levels recorded in the USDA National Nutrient Database for mature leaves. Although vitamin and antioxidant levels varied, levels measured in microgreens were up to 40 times higher than those recorded for more mature leaves. Therefore, although microgreens generally appear to contain higher nutrient levels than more mature plants, this may vary based on the species at hand.

Health Benefits of Microgreens

Eating vegetables is linked to a lower risk of many diseases. This is likely thanks to the high amounts of vitamins, minerals and beneficial plant compounds they contain. Microgreens contain similar and often greater amounts of these nutrients than mature greens. As such, they may similarly reduce the risk of the following diseases:

Heart disease: Microgreens are a rich source of polyphenols, a class of antioxidants linked to a lower risk of heart disease.

Animal studies show that microgreens may lower triglyceride and “bad” LDL cholesterol levels.

Alzheimer’s disease: Antioxidant-rich foods, including those containing high amounts of polyphenols, may be linked to a lower risk of Alzheimer’s disease.

Diabetes: Antioxidants may help reduce the type of stress that can prevent sugar from properly entering cells. In lab studies, fenugreek microgreens appeared to enhance cellular sugar uptake by 25–44%.

Certain cancers: Antioxidant-rich fruits and vegetables, especially those rich in polyphenols, may lower the risk of various types of cancer. Polyphenol-rich microgreens may be expected to have similar effects.

Growing Micro Greens

Microgreens are generally described as being an easier plant to grow but may have complication ranging from preventing and managing fungus or mold growth to providing the right nutrients and growing media to the plants in order to ensure quality produce. Many small "backyard" growers have sprung up selling their greens at farmers markets or to restaurants. A shallow plastic container with drainage holes, such as a nursery flat or prepackaged-salad box, will facilitate sprouting and grow out on a small scale. However, for commercial scale growing, specific trays better suited to growing and supporting microgreens are used.

Growing and marketing high-quality microgreens commercially is more intensive, but also shows potential for providing better quality produce under controlled and sterile environments and could provide local communities with better nutritional diversity at scale. Artificial lighting is not necessarily needed for growing microgreens but is required for indoor commercial setups. Microgreens can grow under various lighting conditions, including indirect natural light and grow lights, but some source of light is necessary for them to have grown adequately enough for harvest. Different lighting conditions can change the flavors of the microgreens being grown. For instance, corn microgreens are sweet when grown in the dark, but become bitter when exposed to light due to photosynthesis processes taking place in the sprouting plants.

Light-emitting diodes, otherwise known as LEDs, now provide the ability to measure impacts of narrow-band wavelengths of light on seedling physiology. The carotenoid zeaxanthin has been hypothesized to be a blue light receptor in plant physiology. A study was carried out to measure the impact of short-duration blue light on phytochemical

compounds, which impart the nutritional quality of sprouting broccoli microgreens. Broccoli microgreens were grown in a controlled environment under LEDs using growing pads. Short-duration blue light acted to increase important phytochemical compounds influencing the nutritional value of broccoli microgreens. Nightshade family plants such as potatoes, tomatoes, eggplants and peppers should not be grown and consumed as microgreens, since nightshade plant sprouts are poisonous. These sprouts contain toxic alkaloids such as solanine and tropanes, which can cause adverse symptoms in the digestive and nervous systems.

Comparison of microgreens to sprouts

Sprouts are germinated or partially germinated seeds. A sprout consists of the seed, root, stem, while microgreens are harvested without the roots. Microgreens have stronger flavors compared to sprouts, and come in a wider selection of leaf shapes, textures, and colors.

Microgreens are grown in soil or soil-like materials such as peat moss.^[11] Microgreens require high light levels, preferably natural sunlight with low humidity and good air circulation. Microgreens are planted with very low seed density compared to sprout processing. Crop times are generally one to two weeks for most varieties, although some can take four to six weeks. Microgreens are ready to harvest when the cotyledons are fully expanded. Harvesting is usually with scissors cutting just above the soil surface, excluding any roots. Some growers sell them while still growing, rooted in the growing trays so that they may be cut later. Once removed from their growing environment, these trays of microgreens must be used quickly, or they will rapidly begin to elongate and lose color and flavor.

Sprout seeds are soaked in water, usually for eight hours, and then drained. A high density of seed is placed inside of sprouting equipment or enclosed containers. The seed germinates rapidly due to the high moisture and humidity levels maintained in the enclosures. Seeds can also be sprouted in cloth bags that are repeatedly soaked in water. The sprouting process occurs in dark or very low light conditions. After a few days of soaking and repeated rinsing in water (several times a day to minimize spoilage), the processing is complete, and the sprouts are ready to consume.

The conditions that are ideal for properly grown microgreens do not encourage the growth of dangerous pathogens. These growing methods would not work for the production of sprouts. However, the potential for food safety issues with microgreens may be increasing due to



the number of indoor microgreen growing operations in which excessive seed density, low light intensity, low air circulation, or most commonly, a lack of GAP (good agricultural practices) and GMP (good manufacturing practices) based food safety procedures. Certain provisions of the *Guidance for Industry: Reducing Microbial Food Safety Hazards For Sprouted Seeds* may be beneficial and prudent for growers of microgreens to follow. Also, not all plants can be grown as microgreens due to toxicity concerns. For instance, nightshade plants (eggplants, tomatoes, potatoes, peppers, etc.) should not be grown as microgreen sprouts, since nightshade sprouts are toxic.

AN INSIGHT INTO THE RECENT TRENDS IN BIOSENSORS FOR DETECTING FOOD ADULTERATION

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Abstract

Biosensors have revolutionized the field of food industry by offering highly sensitive, rapid, and portable detection methods for various contaminants, pathogens, and quality parameters in food products. Nano biosensors enable the detection of contaminants such as pesticides, heavy metals, and toxins in food products at extremely low concentrations. This ensures the safety of food products by identifying potential hazards before they reach consumers. Nano biosensors can detect foodborne pathogens such as *Salmonella*, *E. coli*, and other harmful microorganisms with high sensitivity and specificity. Rapid detection of these pathogens helps prevent foodborne illnesses and outbreaks, enhancing food safety. Nano biosensors can assess various quality parameters in food products, including freshness, spoilage, and nutritional content. They can detect indicators of spoilage such as microbial metabolites and gas emissions, allowing for timely interventions to maintain product quality and shelf life. Nano biosensors are capable of detecting allergenic ingredients in food products, such as peanuts, gluten, and soy, even at trace levels. Accurate allergen detection is crucial for preventing allergic reactions in sensitive individuals and ensuring compliance with labelling regulations. Biosensors can be miniaturized and integrated into portable devices, enabling on-site testing and real-time monitoring throughout the food supply chain. This facilitates rapid decision-making, reduces the need for centralized laboratory testing, and minimizes delays in product distribution. Nano biosensors offer cost-effective solutions for food testing compared to traditional methods, which often require expensive equipment and reagents. Their miniaturization and scalability contribute to reduced operational costs and increased accessibility to testing technologies.

Nano biosensors can be used for traceability and authentication purposes, allowing stakeholders to verify the origin, authenticity, and compliance of food products with labelling and certification standards. Overall, nano biosensors have transformed the food industry by enhancing food safety, quality control, and efficiency throughout the supply chain, ultimately benefiting both consumers and food producers.

Keywords: Food; Nanomaterials; Adulteration; Contamination; Sensors; Safety.

Introduction

Recent days have seen an upsurge in nano biosensors that have been an area of active research and development, showing significant potential in various fields such as healthcare, environmental monitoring, and food safety. Researchers have been focusing on improving the sensitivity and selectivity of nano biosensors. This involves the development of novel nanomaterials and surface functionalization techniques to enhance the detection of analytes with high precision even at low concentrations.

Nano biosensors are advanced analytical tools employing nanotechnology for the detection and quantification of biomolecules, with applications spanning environmental monitoring, food safety, and biomedical diagnostics. These sensors leverage the unique properties of nanomaterials to achieve improved sensitivity, specificity, and rapid response, making them valuable across diverse fields beyond healthcare [1]. Nano biosensors play a vital role in identifying food adulteration, with various examples demonstrating their efficiency [2]. Electrochemical nano biosensors, including those based on nanotubes, detect contaminants like heavy metals and pesticides by monitoring shifts in electrical signals when these substances interact with the sensor's surface, allowing for quick differentiation of anions and cations in food [3]. Aptamer-based biosensors, which utilize specific DNA or RNA sequences to target substances such as antibiotics and pesticides, identify these compounds through structural transformations upon binding [4]. Colorimetric sensors enhanced with nanoparticles, such as gold nanoparticles for melamine detection in milk, produce visible colour changes when they come into contact with certain adulterants [5]. Fluorescent quantum dot-based sensors, made up of semiconductor nanomaterials that emit light upon stimulation, detect harmful microorganisms by binding to specific bacteria, providing an optical signal to indicate contamination [6].

Biosensors are used to detect contaminants, pathogens, toxins, and allergens in food products. Rapid and sensitive detection of these hazards ensures that contaminated products are identified

and removed from the supply chain before reaching consumers, thereby safeguarding public health and preventing foodborne illnesses. Biosensors are employed to monitor various quality parameters in food products, including freshness, spoilage, nutritional content, and authenticity. By detecting indicators of spoilage and degradation, biosensors help ensure that food products meet quality standards and maintain their integrity throughout storage and distribution. Biosensors assist food manufacturers in complying with regulatory standards and labelling requirements. By detecting allergenic ingredients, genetically modified organisms (GMOs), and other regulated substances, biosensors help ensure that food products are accurately labelled and comply with food safety regulations. Biosensors are used for real-time monitoring of food processing operations, such as fermentation, pasteurization, and sterilization. By monitoring critical process parameters, biosensors help optimize production processes, reduce waste, and ensure consistency in product quality. Biosensors enable traceability and authentication of food products throughout the supply chain. By tracking the origin, handling, and distribution of food products, biosensors help prevent food fraud, counterfeit products, and adulteration, thereby ensuring transparency and accountability in the food industry. Biosensors offer rapid and cost-effective methods for food testing compared to traditional laboratory techniques. By providing quick results on-site or in the field, biosensors minimize the time and resources required for sample preparation, transportation, and analysis, leading to increased efficiency and productivity in food testing operations. Biosensors are indispensable tools in the food industry for ensuring food safety, quality control, regulatory compliance, process optimization, supply chain management, and consumer satisfaction. A brief summary of the various applications of nano biosensors is shown in Figure 1.

Food adulteration refers to the practice of incorporating unwanted substances into food items, typically to mislead consumers or maximize profits [7]. Artificial food dyes, such as Red 40 and Yellow 5, are added to products like candies and beverages to enhance their appearance, but excessive intake may have adverse health effects [8]. Starch is commonly incorporated into dairy products to increase volume, giving a false impression of their actual composition. Similarly, water is sometimes added to milk and fruit juices to extend quantity, which lowers their nutritional value. Artificial sweeteners like saccharin and aspartame are used to provide sweetness without additional calories, though concerns about their safety persist [9]. Toxic metals, including lead, mercury, and cadmium, may enter food due to environmental pollution or

faulty processing methods, posing significant health risks [10]. Low-cost flours are sometimes blended with premium-quality ones to cut production expenses, while ghee and edible oils may be diluted with inferior fats, altering their taste and nutritional benefits [11]. Honey is often mixed with sugar or corn syrup to increase quantity, which reduces its natural flavour and health properties [12]. Spices such as turmeric and chili powder may contain synthetic colouring agents or fillers, compromising their quality and potentially leading to health concerns [13].

Nano biosensors play a vital role in detecting food adulteration by utilizing a transducer that translates biological interactions into digital signals, allowing for precise identification of contaminants [14]. Their exceptional sensitivity and selectivity make it possible to detect even minimal traces of harmful substances and pathogens, contributing to improved food safety [15].



Figure 1. Various Applications of Biosensors in food industry

These sensors contain nanocarriers that attach to pollutants and impurities, enhancing their ability to identify toxins such as mycotoxins and harmful microorganisms throughout different stages of food processing, from production to packaging [16]. Many of these devices incorporate enzyme-based catalysts that respond to environmental factors like temperature and pH, necessitating careful assessment to maintain their stability and effectiveness [17]. Some nanobiosensors are embedded in intelligent packaging systems, providing real-time data on food

quality and alerting both consumers and manufacturers to possible contamination or spoilage [18].

NANOTECHNOLOGY IN BIOSENSORS

Biosensors offer exceptional sensitivity, specificity, and rapid response times, making them a vital tool for detection and measurement. Their applications have significantly advanced scientific and technological progress in various fields. Biosensors have a broad range of applications in food adulteration detection. Traditional biosensors were inspired by natural biological sensing systems, such as the olfactory abilities of dogs or the electro sensitivity of sharks, and typically relied on in vitro techniques to replicate these mechanisms. Over the last few decades, there has been a major shift towards integrating nanotechnology into biosensor design. This shift is driven by the ability to create nanoscale materials, such as nanoparticles, nanotubes, and nanowires, that exhibit unique physical and chemical properties. These nanomaterials allow biosensors to directly interact with biomolecules, significantly enhancing their functionality. Nano biosensors offer several advantages, including increased sensitivity due to their large surface area-to-volume ratio, which enables more efficient capture and analysis of target biomolecules. This enhanced sensitivity leads to improved detection of specific analytes and a more accurate localization of biomolecular changes associated with diseases. Additionally, nano biosensors can employ a wide variety of transduction mechanisms, such as electrical, optical, thermal, and magnetic techniques, providing versatility across different fields of application. This versatility has also advanced disease detection and monitoring, allowing for more detailed biomolecular profiling, which aids in therapeutic assessments and tracking disease progression. Despite these advantages, there are still challenges that need to be addressed. These include issues like signal drift, fouling, and non-specific interactions, which can lead to unreliable transduction signals and complicate the interpretation of results. Furthermore, the release of nanoparticles into the environment raises concerns about their potential toxicity, which could pose risks to both human health and the environment [17].

Nanomaterials have revolutionized biosensor technology by enhancing sensitivity, specificity, and detection capabilities across various applications. Among these, different types of nanomaterials, including metal-based, carbon-based, and semiconductor nanoparticles, play a crucial role in advancing biosensing techniques [19].

Graphene consists of a single layer of carbon atoms organized in a two-dimensional hexagonal structure. Its outstanding electrical conductivity, combined with an extensive surface area, makes it highly suitable for biosensing applications. This material has the ability to interact efficiently with various biomolecules, thereby improving the sensitivity and selectivity of biosensors. Gold nanoparticles play a crucial role in biosensor technology due to their distinct optical and electronic characteristics. Their strong affinity for biomolecular interactions makes them particularly useful in colorimetric detection methods, where visible colour shifts indicate the presence of target analytes. Additionally, their biocompatibility and ease of surface modification make them a preferred choice for diverse biosensing applications. Similar to gold nanoparticles, silver nanoparticles exhibit plasmonic properties that make them highly effective in biosensing applications. They are particularly useful in Surface-Enhanced Raman Spectroscopy (SERS)-based biosensors, enabling improved signal detection [19]. Additionally, their role in colorimetric sensing allows for visual identification of target analytes through distinct colour changes.

These nanoparticles are specifically utilized in lateral flow assay (LFA) biosensors for detecting clenbuterol. Their strong affinity for target antibodies facilitates precise recognition, producing visible colorimetric changes that indicate the presence of the target substance. Magnetic nanoparticles can be functionalized with biocompatible coatings, making them suitable for targeted delivery and biosensing applications. Their ability to respond to external magnetic fields allows for precise control over biosensing targets, while also enhancing signal detection in electrochemical sensors, improving overall sensitivity and performance. This category includes nanomaterials such as graphene and carbon nanotubes, both of which possess excellent conductivity, high surface area, and biocompatibility. These properties make them ideal for immobilizing biomolecules and facilitating efficient electron transfer, leading to improved biosensor sensitivity and performance. Two-dimensional materials like molybdenum disulfide (MoS_2) have garnered attention in biosensor development due to their distinctive electrical characteristics. Their semi-conducting nature and wide bandgap provide advantages over traditional carbon-based materials in certain applications, making them highly effective for next-generation biosensing technologies. Renowned for their luminescent capabilities, upconverting nanoparticles are particularly valuable in optical biosensors.

They possess the unique ability to convert near-infrared light into visible light, enhancing detection in low-light conditions, which is crucial for highly sensitive biosensing applications. Quantum dots are semiconductor nanomaterials that exhibit remarkable optical properties, including fluorescence emission. Their tunable light-emitting characteristics make them highly suitable for a wide range of biosensing applications, particularly in fluorescence-based detection systems where high sensitivity and specificity are required. Building upon the diverse range of nanomaterials used in biosensors, their unique properties play a crucial role in enhancing signal transduction, surface functionalization, and amplification strategies, further improving the sensitivity and efficiency of detection systems. Nanomaterials play a crucial role in enhancing signal generation and transmission within biosensors through multiple mechanisms [19] as given below;

1. **Enhanced Electrical Properties:** Materials like graphene, carbon nanotubes, and metallic nanoparticles exhibit remarkable electrical conductivity, facilitating efficient charge transfer between the biosensor interface and target biomolecules. This results in stronger and more reliable signal output during detection.
2. **Expanded Surface Area:** Due to their nanoscale structure, these materials provide an extensive surface area, promoting increased interactions with biological molecules. This heightened interaction significantly improves the conversion of biological events into quantifiable signals, thereby boosting sensor sensitivity.
3. **Innovative Signal Conversion Mechanisms:** Nanostructured materials introduce novel transduction approaches, such as electrochemical and optical techniques, that are unattainable with bulk materials. For instance, quantum dots enhance fluorescence signals, enabling the detection of trace amounts of analytes with high precision.

Surface Functionalization for enhanced activity

Optimizing the surface of nanomaterials is essential for enhancing their biocompatibility and target specificity in biosensor applications [19]:

- **Biomolecule Attachment:** Covalent or non-covalent binding of biomolecules such as antibodies, enzymes, or nucleic acids to nanomaterial surfaces improves their selectivity for specific analytes. This targeted interaction minimizes potential interference from other substances present in the sample.

- **Customized Functional Groups:** Modifications with chemical groups like carboxyl, amine, or thiol promote selective interactions with biological molecules, enabling stable and efficient molecular recognition. Such tailored surface modifications enhance the accuracy and reliability of biosensors.
- **Improved Biocompatibility:** Functionalized nanomaterials exhibit reduced cytotoxicity and increased stability, making them suitable for biomedical applications. This ensures prolonged sensor performance, particularly in clinical and diagnostic settings.

Signal Amplification Strategies

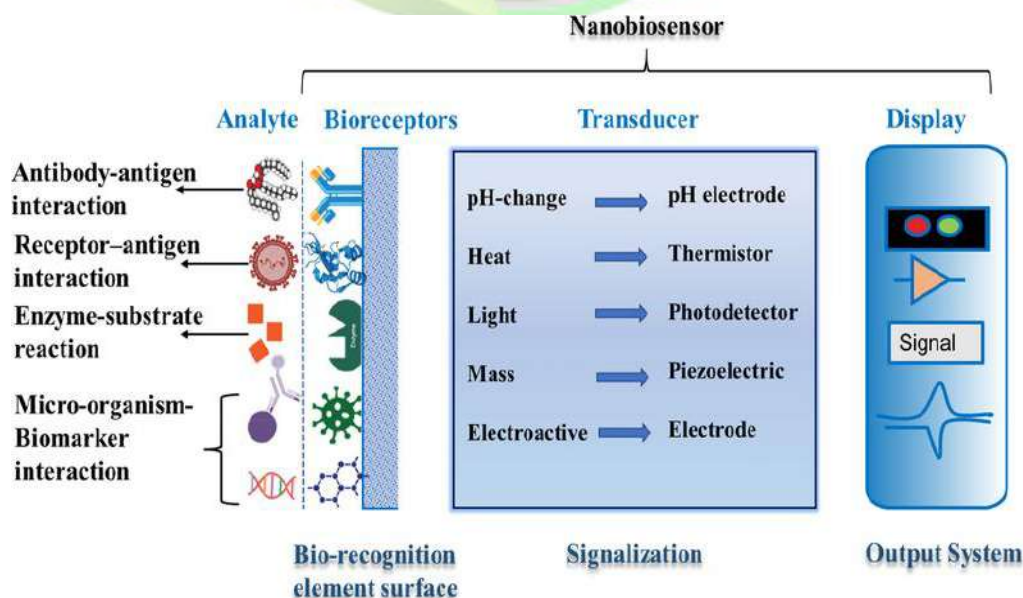
Nanotechnology-based biosensors utilize various techniques to amplify detection signals for greater sensitivity [17]:

Enzymatic Signal Enhancement: The incorporation of enzyme-based amplification mechanisms allows for increased signal output. Enzyme-linked probes catalyze reactions that produce detectable byproducts, strengthening the overall biosensor response.

Nanoparticle Aggregation and Multiple Signal Pathways: Clustering nanoparticles on the sensor surface generates localized electromagnetic field enhancements, significantly boosting detection sensitivity in methods like surface-enhanced Raman scattering (SERS).

Molecular Probe Integration: Functional probes that exhibit fluorescence or electrochemical responses upon binding to target molecules enhance signal intensity, making even trace-level contaminants or biomarkers detectable with high accuracy.

Figure 2: A schematic depiction of nanobiosensors, their interactions, and constituent parts.



The integration of nanotechnology into biosensors has significantly enhanced their capabilities, offering improved sensitivity, versatility, and precision, while opening up new avenues for applications in disease detection, environmental monitoring, and beyond. However, continued research and development are crucial to overcoming existing challenges and unlocking the full potential of nano biosensors for widespread use. There are many benefits such as low sample size requirements, mobility, sensitivity, and cost effectiveness and in some situations their stability needs to be enhanced before they can be used successfully in the commercial sector. In comparison to the current generation of standard sensors, nano sensors guarantee quick and accurate detection of toxins, adulterants, and microbes. When it comes to improving food safety and quality assurance and identifying food adulteration, nano biosensors are a great advantage. They are perfect for detecting pollutants in intricate food matrices because to their quick reaction times and high sensitivity, meeting consumer demands for accountability and traceability in food supply chains. Nano biosensors have emerged as a groundbreaking tool in food safety, offering unparalleled sensitivity and rapid detection of contaminants. However, despite their promising benefits, concerns regarding potential health risks, environmental impact, and regulatory challenges must be carefully addressed for their safe and effective application.

Conclusion

Nano biosensors play a vital role in detecting food adulteration by utilizing a transducer that translates biological interactions into digital signals, allowing for precise identification of contaminants. Their exceptional sensitivity and selectivity make it possible to detect even minimal traces of harmful substances and pathogens, contributing to improved food safety. These sensors contain nanocarriers that attach to pollutants and impurities, enhancing their ability to identify toxins such as mycotoxins and harmful microorganisms throughout different stages of food processing, from production to packaging. Many of these devices incorporate enzyme-based catalysts that respond to environmental factors like temperature and pH, necessitating careful assessment to maintain their stability and effectiveness. Some nano biosensors are embedded in intelligent packaging systems, providing real-time data on food quality and alerting both consumers and manufacturers to possible contamination or spoilage.

Nanotechnology is at the core of advances in biological research. Nanotechnology plays vital role in biosensors by enabling the development of miniaturized, highly sensitive, and precise detection systems using nanomaterials and nanostructures, revolutionizing the field of

biosensing. Maximizing the surface area of nanomaterials and functionalizing them with specific ligands enhances the binding affinity and selectivity of biosensors, improving the detection sensitivity. Nanomaterials, particularly Nanoparticles, often exhibit quick and real-time detection of biological molecules. Nanomaterials can enhance the stability and longevity of biosensors. Functionalizing biosensors surfaces with nanoparticles can protect the biological components from degradation, improving the shelf life and reliability of biosensors. Nanotechnology enables multifunctional biosensors, development of Wireless and remote biosensors by integrating different types of nanomaterials. Nano Biosensors play a crucial role in enhancing food safety and security by enabling sensitive, rapid, multiplex, and portable detection of adulterants in food samples. In conclusion, the implementation of nano biosensors in the food industry is not just desirable but imperative. These cutting-edge technologies offer unparalleled capabilities in detecting contaminants, ensuring food safety, and enhancing quality control measures. Embracing nano biosensors holds the promise of revolutionizing food safety protocols, thereby safeguarding public health and consumer confidence in the integrity of the food supply chain. As we navigate increasingly complex challenges in food production and distribution, the integration of nano biosensors stands as a crucial step towards a safer, more efficient, and sustainable food industry.

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HIDDEN LIVES ON THE MORINGA TREE: A CLOSER LOOK AT INSECT EGG-LAYING BEHAVIOUR

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Abstract

Plants are not just static life forms but thriving micro-ecosystems supporting countless interactions. This article explores a simple yet intriguing observation: a line of tiny yellow eggs on a Moringa (*Moringa oleifera*) plant. Through this lens, we delve into insect egg-laying behaviour, plant-insect relationships, and broader ecological dynamics. A seemingly small event, a moth laying eggs, unfolds into a story of survival, interdependence, and hidden beauty in nature. This narrative highlights why close observation of common plants can reveal complex ecological interactions worth celebrating and protecting.

Introduction

The world we walk through daily is full of life that often goes unnoticed. Plants, for instance, are not just a “green background” to human activities; they are bustling hubs where insects, microbes, birds, and even mammals meet, interact, and sometimes clash. One such plant, the *Moringa oleifera* tree, revered for its nutritional and medicinal value, also hosts a wide range of small but vital life forms. When a trail of neatly arranged yellow eggs appeared on a Moringa plant, it opened a window into the fascinating world of insect reproduction, survival strategies, and ecological relationships. This article traces that simple observation into a broader story of ecological complexity and beauty.

The Moringa Tree: More than Just a Superfood

Moringa oleifera, native to the Indian subcontinent but now grown worldwide, is often called the “miracle tree” due to its fast growth, drought resistance, and nutritional richness

(Fahey, 2005). Its leaves are packed with vitamins, minerals, and antioxidants, making it a vital food source in many developing regions. Beyond its human uses, Moringa also plays a critical role in natural ecosystems. Its tender leaves, soft stems, and clusters of flowers attract a wide range of insect visitors, from pollinators to herbivores to predators. By hosting insect life, Moringa trees support broader food webs, including birds, reptiles, and small mammals.

Insect Reproduction and Egg-Laying Behaviour

Insects have evolved incredible strategies to ensure the survival of their offspring. Most insects lay large numbers of eggs, often in specific patterns or hidden places, to maximize survival chances against predators, parasitoids, and environmental hazards (Wigglesworth, 2012). Choosing the right plant to lay eggs is crucial. herbivorous insects often specialize in particular host plants that provide the right nutrition and chemical defences their larvae can tolerate (Schoonhoven et al., 2005). With its tender tissues, Moringa may seem like an ideal nursery for caterpillars despite its mild chemical defences, which their larvae can tolerate (Schoonhoven et al., 2005). Moringa, with its tender tissues, may seem like an ideal nursery for caterpillars despite its mild chemical defences.

Case Study: Yellow Eggs on Moringa

The eggs observed on the Moringa plant formed a neat line around a stem, typical of certain moths. Species such as the Oleander Hawk Moth (*Daphnis nerii*) are known for laying eggs on soft-stemmed plants where their voracious caterpillars can later thrive (Scoble, 1992). The yellow colour suggests freshness; as they develop, insect eggs often darken as the embryo matures inside. The clustering strategy could protect the eggs by overwhelming predators with too many for them to consume at once or by simply blending in with the plant structure. Each egg, no bigger than a pinhead, contains a complete blueprint for transformation: from embryo to larva, to pupa, and eventually to adult moth.



Figure 1. Eggs laid on Moringa (*Moringa oleifera*)

The Lifecycle: from Egg to Adult

Within a few days of laying, if environmental conditions are favourable (adequate moisture, temperature, and protection), the eggs hatch into tiny caterpillars. Their first act is to start feeding, sometimes even eating, the eggshell itself for extra nutrition. The caterpillars grow rapidly, moulting several times as they increase in size. During this time, they consume significant amounts of leaf material, which can sometimes stress or even defoliate young plants. After a series of moults, the mature caterpillar seeks a secure place to pupate, spinning a cocoon or burrowing into the soil. After weeks or months (depending on species and climate), the adult moth emerges, ready to seek mates and continue the cycle (Gullan & Cranston, 2014).

Ecological Balance: Pests or Partners?

To farmers and gardeners, caterpillars are often seen as pests. Heavy infestations can severely damage crops and reduce yields. Yet, in natural ecosystems, caterpillars are vital prey for many species: birds, predatory insects, spiders, and parasitic wasps all depend on them (Price et al., 2011). Furthermore, moderate herbivory can stimulate plant growth, encouraging the plant to produce new shoots and strengthening overall ecological resilience (Karban & Baldwin, 2007). Thus, caterpillars, the eggs they hatch from are essential components of healthy ecosystems.

Human Perspectives: Protect or observe?

Faced with insect eggs on valuable plants, humans have two basic choices: intervene or observe. Conventional agriculture often opts for intervention-mechanical removal, insecticidal sprays, or biological controls. Organic and ecological farming approaches, however, encourage balancing pest populations naturally through habitat diversification and predator support (Altieri, 1999). For backyard gardeners and nature enthusiasts, observing the life cycle can be deeply rewarding. Watching tiny caterpillars grow, moult, and metamorphose into stunning moths reminds us that nature's magic is often small, silent, and slow. Additionally, citizen science initiatives encourage people to document such findings, contributing valuable data to ecological studies and conservation efforts (Silvertown, 2009).

Conclusion

The tiny yellow eggs on the Moringa tree are more than just potential pests—they are a testament to life's persistence, complexity, and interconnectedness. They remind us that even



ordinary plants host extraordinary stories. By choosing to look closely, appreciate, and understand, we reconnect with the rich, unseen layers of the natural world that support and sustain us all.

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GENE-EDITED INSECTS: FARMING'S FUTURE OR ECOLOGICAL GAMBLE

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Abstract

Agriculture stands at a crossroads. Pesticide resistance, biodiversity loss, and climate-induced pest migration are undermining food security. Amidst these pressures, gene-edited insects-engineered using CRISPR and enhanced sterile insect techniques (SIT)-have emerged as a bold new frontier in crop protection. These genetic tools offer targeted pest suppression with less environmental fallout than traditional chemical pesticides. But the promise comes bundled with serious ecological, ethical, and regulatory questions. This article explores the science behind gene-editing in pest control, presents expert voices from farmers, researchers, and environmentalists, and weighs whether gene-edited insects are a sustainable breakthrough or an irreversible ecological risk.

Introduction: The Insect Paradox

Insects serve as vital pollinators, decomposers, and food web constituents, yet they also include some of the world's most damaging crop pests. Historically, synthetic pesticides helped suppress pest populations, but at significant ecological cost-including resistance, contamination of water bodies, and collapse of non-target species (Clark & Hillocks, 2014). Innovations in molecular biology now provide precision tools to control pest species at the genetic level. CRISPR (Clustered Regularly Interspaced Short Palindromic Repeats) allows scientists to cut and modify specific DNA sequences in living organisms. Combined with SIT-a technique dating back to the 1950s where sterilized males are released to mate with wild females-gene editing may offer a cleaner, smarter solution to pest outbreaks.

However, such interventions are complex, permanent, and entangled in social, political, and ethical considerations.

Gene-Editing and Sterile Insect Technique: The Science

CRISPR-Cas9 enables scientists to delete or replace genes with high specificity. In pest management, geneticists focus on modifications that:

- Sterilize males by disabling fertility genes
- Cause female offspring to die early
- Spread these changes through populations via “gene drives”

SIT has historically relied on radiation to sterilize insects, but this often weakens them, reducing their competitiveness. Gene-editing offers a way to produce sterile, but otherwise fit, males (Kandul et al., 2019). Companies like Oxitec have applied this method in mosquitoes-releasing genetically engineered *Aedes aegypti* in Brazil and the Florida Keys to combat dengue and Zika. Results showed up to 82% suppression in target populations (Carvalho et al., 2015).

Scientific Promise: Precision with Reduced Pollution

Gene-edited pest control is often framed as an evolution of Integrated Pest Management (IPM)-a shift from blanket sprays to ecological fine-tuning.

Key Advantages:

- **Species-specific targeting:** Minimizes harm to non-target organisms.
- **Environmental safety:** Reduces the volume and toxicity of chemical pesticides.
- **Sustainability:** Delays or avoids resistance when integrated into rotational strategies.
- **Climate adaptability:** Gene-editing can produce strains optimized for local environments.

Field studies on gene-edited *Plutella xylostella* (diamondback moth), *Drosophila suzukii* (spotted wing drosophila), and *Ceratitis capitata* (Mediterranean fruit fly) have demonstrated suppression effects and crop protection in semi-controlled conditions (Li et al., 2020).

Farmer Perspectives: Innovation Meets the Field

Farmers worldwide express both hope and skepticism. In India’s cotton belt, Rajiv Sharma is cautiously optimistic: “Sprays work for a while, but the bollworms always return. If edited insects can hold them off without harming bees or soil, that’s powerful-but only if it’s affordable and fair.” Kenya’s Central Highlands hosted gene-drive trials for fruit fly control. Farmer Mary Wanjiru participated and was impressed with reduced crop loss. “But we must

understand what's happening. Don't release something in our fields without our consent." Cost, transparency, and access are recurring themes among smallholders. Many want the benefits but fear corporate monopolies and lack of local input.

Environmental Concerns: Ecological Unknowns

Critics warn of unintended and potentially irreversible consequences. "Once released, gene-edited insects interact with complex ecosystems in ways we cannot fully predict," cautions Maya Esteban from Green Earth Coalition.

Key Concerns Include:

- **Gene flow:** Edits may cross into non-target or wild populations.
- **Trophic cascades:** Elimination of one pest could impact predator-prey dynamics.
- **Ecological replacement:** Removing one pest may allow another to dominate.
- **Recall limitation:** Once released, gene-drive insects are difficult to contain.

Modeling studies show that even self-limiting gene drives can spread unpredictably if insects migrate or hybridize (Noble et al., 2019).

Ethical and Governance Questions: Who Decides?

Beyond the science lie profound questions about power, control, and values:

- **Consent:** Should communities have the right to accept or reject releases?
- **Equity:** Will technologies benefit smallholders or favor corporations?
- **Biodiversity ethics:** Do humans have the right to reprogram wild species?

Dr. Lara Okafor, a Nigerian bioethicist, emphasizes democratic oversight: "In many countries, biosafety laws are outdated or missing. Without public dialogue, we risk exporting risk to the Global South while profits flow elsewhere."

Policy and Public Engagement: Bridging the Gap

The regulatory picture is fragmented. In the U.S., gene-edited insects are treated as biopesticides under the Environmental Protection Agency (EPA), while the European Union remains cautious under its strict GMO laws. African nations are developing biosafety protocols but face resource gaps. Public trust hinges on transparency. Studies in Kenya and Brazil show that people are more accepting of gene technologies when engaged early and given clear benefits and safety assurances. Effective outreach, local leadership, and fair benefit-sharing will be key.

Conclusion: Engineering the Future of Pest Control

Gene-edited insects promise a dramatic shift in how we think about pest management. They offer precision, sustainability, and the potential to complement ecological farming. Yet these technologies also introduce irreversible ecological changes, legal ambiguity, and social tensions. As we edit insects, we must also edit our approach—balancing innovation with humility, inclusion, and long-term ecological vision. Science must partner with society, ensuring that the future of farming is not only high-tech but also just and resilient.

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MOLECULAR MARKERS BASED VALUATION OF GENETIC DIVERSITY IN *ABELMOSCHUS ESCULENTUS*

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Abstract

Being a rich source of supplements, minerals, and filaments in okra, it has additionally pulled in contamination of numerous microbes and diseases. Since it is the primary objective in okra reproducing to expand yield with insignificant disaster because of low contamination, for its supplement cases. In okra's differing wild genetic stock, it holds a safe wellspring of qualities for some natural burdens. However, tackling the issue of ailments and insect's invasion in okra by usual reproducing approach currently helps progression markers in sub-atomic and biotechnological methods from helped determination and safe quality exchange. Since Restriction Fragment length polymorphism (RFLP) markers have been frequently created, issues have been continually altered for expanded convenience as a method for illuminating and bringing computerization into genome investigation, phylogenic examination, quality labeling, and determination of required genotypes. The accomplishment of these innovations to achieve hereditary improvement in crop plants will rely upon the nearer association between plant raisers and biotechnologists, accessibility of talented labor, and generous monetary resources on research. Morphological markers are not appropriate for assessing hereditary variety because of low differential qualities between species, genera, or their people however utilization of atomic markers for assessing DNA varieties in plants gives basic methodologies in the field of sub-atomic hereditary qualities. They are similarly profoundly impacted by climatic variables. Thusly, the atomic marker framework is an extremely powerful strategy for enumerated DNA fingerprinting of yield plants. Be that as it may, the productive utilization of sub-atomic markers

relies upon solid coordination between plant reproducers, biotechnologists, and prepared labor in crop rearing projects, just as fitting economic help.

Keywords: DNA fingerprinting, gene pool, and morphological markers.

1. Introduction

Okra [*Abelmoschus esculentus* (L.) Moench] is advanced with different nutrients, minerals, calcium, sugars, proteins, and dietary fiber. Okra seed proteins have a decent proportion of amino acids (tryptophan and lysine) when contrasted with different wellsprings of protein present in vegetables. Ongoing headways in sub-atomic science prompt more solid identification of cultivating with an expectation of appropriate qualities, hereditary variety, and unevenness between germplasm. DNA markers are broadly used currently by specialists to obtain fast, practical, solid, and productive results independent of natural change. Presentation of different sub-atomic markers, for example, RAPD, SSR, EST-SSR, and ISSR is a more powerful approach to abuse heterosis measures when consistent with phenological characters. Atomic information acquired from assorted germplasms can be utilized to assess and affirm the connections amongst morphological and genetic boundaries for okra crop improvement programs (Duzyaman, 2005). Yet, little data is accessible of okra rearing with connection to the sub-atomic methodologies.

Since ancient times, morphological markers were utilized to measure hereditary varieties just as wanted side effects. The hypothetical advantages of utilizing hereditary markers and the likely estimation of hereditary marker linkage maps and direct choice in plant proliferation were first detailed around 80 years back (Alcaraz and Hormaza, 2007; Anjum *et al.*, 2018). The utilization of morphological markers is being disposed of as these are affected by ecological conditions and formative stages, causing challenges during the ID of homozygous and lopsidedness people. DNA-based sub-atomic markers have filled in as adaptable apparatuses and have discovered their situations in different fields, for example, sequence, plant reproducing, hereditary designing (Joshi *et al.*, 2011).

Marker is a usual minute of DNA that speaks to varieties at the genome level and the coming of sub-atomic methods throughout the years has given simple and exact distinguishing proof of plant species and genera. Atomic markers have been utilized for a depiction of germplasm, hereditary variety, development, recognizable proof of clones or half and halves, appraisal of hereditary relationship, phylogenetic examination, transformative relationship,

arrangement, representation, quality planning, and genome labeling (Zhang *et al.*, 2012; Yang *et al.*, 2015).

In the previous thirty years, DNA-based markers and recombinant DNA innovation have been utilized to physical guides of productivity in huge scope genomic, cytogenetic, and crop plants and sub-atomic markers, ideal properties of major or co-predominant inheritance. Incorporates polymorphism between research facilities, minimal effort, simple access, and a significant level of adaptability (Mondini *et al.*, 2009). Agriculture crops have additionally been dealt with during the most recent years in the field of sub-atomic markers however a combine of features have been made in okra. Cautious determination of atomic markers is significant because no sub-atomic marker meets every one of these attributes (Kour *et al.*, 2014).

To consider a valuable extra apparatus in helped choice plant rearing projects to make plant hereditary qualities atomic marker determination more proficient reproducing organizations have started utilizing markers to expand viability in reproducing and essentially abbreviate the hour of improvement of assortments to changing degrees in the course of recent many years (Bueren *et al.*, 2010). The important instruments of the turbulence to change the area have been a huge scope investigation of sub-atomic marker plant genomic, making sub-atomic markers valuable for plant genomic examination. (Joshi *et al.*, 2011). The most significant forward leap in horticultural biotechnology in the hereditary instrument behind financially significant attributes is originating from the structure and exploration of the genome. The deprived and quick movement of single quality marker preparation and genomics in different types of high plants discipline otherwise called atomic science, the recognizable proof, area, impact and arrangement of data about the capacity of qualities influencing such characteristics which specialists have been distinguishing. Hence, this survey shows the advantages, impediments, and compatible use of customary nurture with the sub-atomic innovation which is a wellspring of data for okra crop improvement programs.

2. ARRANGEMENT OF MOLECULAR MARKERS

2.1. Non-polymerase chain response Based Markers

The principal hereditary marker created and utilized for identification of DNA varieties and development of genomic maps in people was Restriction Fragment length polymorphism (RFLP) (Botstein *et al.*, 1980) in the discovery of DNA polymorphism (Agarwal *et al.*, 2008). Subsequently, numerous sub-atomic markers were created for plant hereditary examination

(Sofalian, *et al.*, 2008). RFLPs are utilized for assessment of hereditary variety and to look at the relationship of firmly connected taxa (Staub *et al.*, 2006). Plants can reproduce their DNA with high exactness and rate, however, numerous systems causing a change in the DNA are employable (Joshi *et al.*, 2011). Genomic limitation part of various lengths between genotypes can be recognized in southern blotting and by an appropriate test examination, it prompts an adjustment in forthright or enormous base-pair bringing about inversion, move, or erasure, bringing about the disaster or advantage of acknowledgment destinations and thusly limitation section of various lengths. In this technique, DNA is processed with limitation protein like EcoR1, which cut the DNA at explicit sequences, electrophoresed, blotting on a layer, and tested with a marked clone. At the point when an F₁ plant goes through meiosis to deliver gametes, it must go through recombination by traverse its chromosomes and recombining it is the premise of conventional hereditary planning and when utilized, RFLP markers, test plant DNA tests require the hybridization of DNA. RFLP markers give an approach to follow chromosome fragments reasonably in recombination as they adhere to Mendelian standards and help essentially in the production of hereditary guides.

2.2. Polymerase Chain Reaction Based Markers

PCR based markers broadly utilized in hereditary examinations incorporate arbitrary enhanced polymorphic DNA (RAPD) (Bardakci, 2001), Amplified fragment length polymorphism (AFLP) (Aktas *et al.*, 2009), microsatellites (SSRs) (Ahmad *et al.*, 2012) just as Inter-Simple Sequence Repeats (ISSRs) (Bornet *et al.*, 2002). After ten years the development of AFLP, there was another advancement which includes the utilization of PCR in 1990 (Farooq and Azam, 2002). PCR, and in vitro strategy for a nucleic corrosive blend, by which a specific portion of DNA can be explicitly repeated (Mullis and Faloona, 1989). The cycle includes two oligonucleotide preliminaries that flank the DNA section of intrigue and intensification is accomplished by a progression of repeated patterns of warmth denaturation of the DNA, tempering of the groundwork to their integral sequences and augmentation of the hardened preliminaries with a thermophilic DNA polymerase. Progressive patterns of enhancement were unavoidably twofold the measure of target DNA amalgamation in the past cycle since extension items supplement the groundwork themselves so the outcome is an exponential gathering of explicit objective portions. Examples of reflected groups would then be able to be utilized forgot genomic fingerprints, which produces genomic DNA from two unique people frequently

extraordinary enhancement and a specific piece starting from an individual, yet the other DNA didn't express to polymorphism and can be utilized as a hereditary marker (Collard *et al.*, 2009).

2.2.1. Randomly Amplified Polymorphic DNA Marker (RAPD)

It recognizes nucleotide arrangement polymorphism in DNA by utilizing a solitary preliminary of self-assertive nucleotide sequence (Oligonucleotide groundwork, generally ten bases in length) (Rosewarne *et al.*, 2006). In this reaction, a type of preliminary strengthens for genomic DNA is applied to two unique locales on correlative strands of DNA layouts. Preferences related to RAPD investigation include:

- (i) The utilization of modest quantities of DNA that make it conceivable to work with populaces that are not available with RFLP. It is quick and effective in investigation having high-thickness hereditary planning as in many plant species, for example, alfalfa (Kiss *et al.*, 1993), bean, and apple.
- (ii) Noninvolvement with radioactive examines (Kiss *et al.*, 1993)
- (iii) Non-prerequisite of species-explicit test libraries
- (iv) Non-contribution in smearing or hybridization.

Restrictions of RAPD markers are:

- (i) Its polymorphism is acquired as major or insufficient characters that cause lost data comparative with markers demonstrating co-strength.
- (ii) Primers are moderately low, even a crisscross of a nucleotide can regularly forestall appending to the groundwork, so the loss of groups happens.
- (iii) Many frameworks experience the ill effects of redundant issues, particularly when moved between populaces or labs as regular markers are needed with helped determination programs (Liu *et al.*, 1994).

2.2.2. Amplified Fragment Length Polymorphism (AFLP)

AFLP is an exceptionally touchy innovation and the additional utilization of fluorescent introduction for computerized volume examination framework and programming bundles to dissect scriptural information makes it profoundly appropriate for an exhaustive investigation. The AFLPS has sections of DNA that have been reflected utilizing preliminaries guided by the boycott of genomic DNA (Bonin *et al.*, 2005). AFLP innovation imparts some strength to both RFLP and RAPD examination (Farooq and Azam, 2002) and consolidates limitation

investigation only with PCR enhancement. Favorable circumstances of AFLP methods (Farooq and Azam, 2002) are:

- (i) Generation of countless polymorphisms.
- (ii) No arrangement data is required
- (iii) The PCR strategy is quick with a high multiplex proportion which settles on the AFLP exceptionally alluring decision.

An ideal marker ought to be adequate variety for the issue under investigation, be solid, and easy to produce and decipher. There are three kinds of issues related to AFLPs and all identified with useful taking care of, information creation, and investigation. These issues are not remarkable to AFLP innovation but rather are likewise connected to other marker frameworks. Lamentably, neither the AFLP nor other DNA markers show these properties. Along these lines, a particular method or procedure chose based on goals be used by and large to accomplish the best outcomes.

2.2.3. Simple Sequence repeat or Short Couple Repeats (SSRs) or miniature satellites

These are on the whole ideal hereditary markers to recognize contrasts between and inside types of qualities of eukaryotes (Farooq and Azam, 2002). It comprises 2-7 base pair units organized in a repeat of mono, di, tri, tetra, and Penta nucleotides (A, T, AT, GA, AG, AAG, and others), with various lengths of repeating themes. These repeats are generally conveyed across plants and creature genomes that seem dependent on contrasts in several repeat units comprising of a locus dependent on significant levels of hereditary variety. Varieties in the quantity of repeated units comprising of a few banding designs distinguished by PCR, (Farooq and Azam, 2002) utilizing locus explicit flanking zone groundwork where they are known. A portion of the key highlights of these markers is that they are key fingerprinting markers and STMS markers (Joshi *et al.*, 2011). The ripeness of microsatellites is with the end goal that they can be utilized productively by different exploration research facilities to create information constantly. Locus-explicit miniature satellite-based markers have been accounted for from many plant species, for example, Lettuce (*Lactuca sativa* L.) (Syed *et al.*, 2006), grain (*Hordeum vulgare* L.), and rice (*Oryza Sativa* L) (Wu and Tanksley, 1993).

Some different microsatellites dependent on a similar guideline incorporate the accompanying:

2.2.3.1. Randomly Amplified Microsatellite Polymorphism (RAMP): This is a miniature satellite-based marker which shows a serious extent of allelic polymorphism, yet they are work escalated (Agarwal and Shrivastava, 2008). RAPD markers then again are economical yet show

a low level of polymorphism. To make up for the shortcomings of these methodologies, a procedure named RAMP was created (Wu *et al.*, 1994). The strategy includes a radiolabeled preliminary comprising of 51 anchors and 31 repeats which are utilized to intensify genomic DNA in the presence or nonappearance of RAPD groundworks. (Agarwal and Shrivastava, 2008).

2.2.3.2. The Sequence Characterized Amplified Region (SCAR): The SCARS are PCR-based markers that speak to genomic DNA sections at hereditarily characterized loci that are distinguished by PCR intensification utilizing arrangement explicit oligonucleotide preliminary (McDermott *et al.*, 1994).

2.2.3.3. Simple Primer Amplification Reaction (SPAR): SPAR utilizes single SSR oligonucleotide standards.

2.2.3.4. Sequence – Related Amplified Polymorphism (SRAP): The point of SRAP strategy (Li and Quiros, 2001) is the intensification of open understanding casings (ORFs). It depends on two-preliminary intensification utilizing AT or GC-rich centers to improve intragenic pieces to identify polymorphism (Agarwal and Shirvastava, 2008).

2.2.3.5. Target area enhancement polymorphism (TRAP): TRAP Technology (Hu and Vicki, 2003) is a brisk and proficient PCR-based innovation that utilizes bioinformatics instruments to produce polymorphic markers around focused competitor quality successions and express sequence tag (EST) information base data. ★ ★ ★ ★

2.2.4. Sequence-based markers

The varieties of a single nucleotide (A, T, G, C) in course of action of plant genome are considered as succession-based markers and are called single nucleotide polymorphism (SNPs) (Randhawa *et al.*, 2013). Generally, these markers are set up from either genomic DNA libraries (RFLPs, SSRs) or RAPDs. MAS is in some cases known as genomics, a type of MAS biotechnology that utilizes hereditary fingerprinting methods to help plant reproducers in coordinating sub-atomic profiles for the physical properties of variety. It is the recognizable proof of DNA arrangements situated close to qualities that can be followed to raise for characteristics that are hard to watch (Barloo and Stam, 1999). MAS alludes to the utilization of DNA markers that are tight-connected to target loci as a substitute for or to help aggregate screening. By deciding the allele of a DNA marker, plants that have specific qualities or quantitative characteristic loci (QTL) might be recognized dependent on their genotype as

opposed to their aggregate. Collard and Mackill (2009), revealed the crucial focal points of MAS contrasted with a traditional phenotypic determination which are: -

- (i) Simpler contrasted with phenotypic rearing
- (ii) It can be chosen in the reproducing stage and single plants can be chosen with high dependability.

In this strategy, linkages are looked for between Selection is made in the reproducing stage and single plants are chosen with high unwavering quality. In this strategy, DNA markers and agronomy request crucial side effects, for example, protection from microbes, bugs, and nematodes, resilience to organic anxieties, the connection between quality boundaries and quantitative indications. DNA markers and agronomic significant characteristics, for example, protection from microbes, bugs, and nematodes, resistance to biotic anxieties, quality boundaries, and quantitative attributes. MAS is as opposed to hereditary designing which includes the fake addition of such people qualities from one life form into the hereditary material of another common, yet not only from other inconsequential species (Salmona *et al.*, 2019).

3. REPRODUCING OF POLYGENIC TRAITS

Exploiting markers can plainly forestall the loss of loci (QTL) regular quantitative trademark with certain harvest DNA markers. It makes us continually express phenotypic varieties to gain proficiency with the hereditary premise of indications as they are plentiful and dispersed all through the genome. The planning populace being adequately enormous can be assessed by utilizing thick hereditary marker maps, contributing various territories of the genome to indication esteems. Also, agronomy, for example, dietary quality, yield, blossom time, and economical obstruction are significant characteristics that follow unpredictable, polygenic legacy designs, in which numerous qualities can without much of a stretch investigate utilizing markers with little impacts on side effect esteem. Confirmations got from different yields demonstrate that even such complex characteristics give off an impression of being dictated by a couple of central points/qualities (Frary *et al.*, 2000; Thornsberry *et al.*, 2001).

4. Use of Molecular Markers in Okra Genome Analysis and Breeding

The atomic markers utilized in genome examination have been viewed as an instrument for an enormous number of utilizations going from a limitation of quality to improving plant assortments by marker-helped choice, which has produced a lot of data and created a few information bases to safeguard and advocate it (Joshi *et al.*, 2011). The original DNA marker

examination is the germplasm portrayal of vegetable engendered crops in IITA, the production of early linkage maps, and the arrangement of plantain/banana zeroed in on the advancement of infection finding in cassava and yam (Ortiz, 2004).

Okra is a significant vegetable in India, West Africa, south-east, Asia, USA, Brazil, Australia, and Turkey, which gives a significant contribution of nutrient and mineral salts including calcium (IBPGR, 1990). Omahinmin and Osawaru (2005) revealed that additional proof is required utilizing sub-atomic markers to explain the morphological variety of significant levels between the promotion of okra. Between wide relations of okra, *Abelmoschus esculentus* demonstrated total encounter to yellow vein mosaic infection (YVMV) and fine mold ailment. *A. ficulneus* and *A. moschatus* escort a more level of opposition just to fine buildup and these germplasms can be expected hereditary assets in rearing okra for YVMV and fine mold obstruction (Samarajeewa and Rathnayaha, 2004). Moreover, Aladele *et al.*, (2008), detailed that 93 increases of okra were surveyed for hereditary peculiarity and connections utilizing RAPD (*i.e* 75 preliminaries utilized). 59 indicated solid and clear intensification, 7 demonstrated powerless enhancement, while 9 preliminaries didn't show any application.

Akash *et al.*, (2020) considered the 30 increase of the Vegetable Gene Bank of Universidade Federal de Viçosa. The examination assessed hereditary variety between morpho agronomic descriptors and okra landrace in Brazil dependent on AFLP markers. For this reason, five blends of 17 morpho genomic descriptors and AFLP preliminaries were utilized. Gower's and Jaccard's were utilizing separation measures for morphological and sub-atomic information, assessing hereditary boundaries for quantitative characteristics and gathering increase by Ward's technique. Polymorphisms were watched for all subjective attributes, while the quantitative characteristics were huge by abnormality investigation. Ward's gathering indicated no association among morpho genomic and atomic information and gatherings shaped with the geological source of the increase. Hereditary boundaries affirmed the presence of fluctuation among increase, and high precision and heredity were found to demonstrate the record identified with foods grown from the ground stature. No association was seen between morpho agronomic descriptors and AFLP markers. The absence of a relationship shows that the two methodologies are significant for comprehension and isolating the increase of okra.

Kumar *et al.*, (2019) was for specialists who had progressed information on their handiness in atomic markers and restricted viewpoints under social yields of blossoms. The

survey presents a diagram of different marker advances and their variations, including different sub-atomic procedures utilized in evaluating plant hereditary variety, particularly their trademark attributes and applications, genotypes, hereditary immaculateness, DNA scanner tags, labeling of significant qualities, improvement of linkage maps, marker-helped choice, and utilization of sub-atomic markers in the tissue culture of bloom social harvests.

Mohammed *et al.*, (2020) investigated and completed to survey the hereditary diversity and populace structure of okra assortments from diverse geographic originating chose polymorphic simple sequence repeat (SSR) markers. 32 okra promotions gathered from three geographic locales were genotyped utilizing 16 chosen SSR markers. The SSR markers created an aggregate of 71 loci of which 67% were polymorphic. Hereditary separations among promotions went from 2.2 to 7.1, with a mean of 4.65. Gene variety went from 0.10 to 0.78 with a mean of 0.52. Hereditary bunching characterized the accessions into three significant groups and four sub-clusters. Each bunch and sub-bunch comprised of accessions derived from different sources. Analysis of sub-atomic change uncovered that 67%, 81%, and 83% of the complete hereditary variety distinguished was found inside populaces of geographic inception, height, and assortment locale, individually. The watched moderate to high populace differentiation could mostly be credited to restricted germplasm exchange, agro-natural contrasts, and halfway by selection pressure. The current examination uncovered the presence of high hereditary variety and populace dissimilarity among okra collections from Ethiopia. The investigation showed that an assortment methodology for preservation of okra hereditary assets should zero in on examining of representative genotypes covering wide geographic districts and altitudinal scopes of target agro-ecologies.

Conclusion

The present review uncovered the presence of high hereditary variety and population difference among okra collections from various seed banks when analyzed using chose polymorphic SSR, RFLP, AFLP, ISSRs markers etc. The genetic diversity was to a great extent credited by contrasts in the geographic beginning, height, and districts of collection of test genotypes. The deduction showed the presence of hereditary variety and populace differentiation of the okra germplasm from Indian seed bank that can be altered in future rearing projects and preservation systems. Further, wild family members and trained sorts of okra win in different districts of India. In this way, further studies are required utilizing bigger and delegate test of

okra employing the as of now tried various markers to completely investigate the hereditary capability of the yield for future rearing or vital preservation.

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VALUE ADDED PRODUCTS IN MORINGA

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Introduction

Moringa (*Moringa oleifera*), often referred to as the "Miracle Tree," is native to India and renowned for its rapid growth and resilience in arid conditions. Its leaves are rich in essential nutrients, making them a valuable resource for addressing malnutrition and enhancing food security. Moringa has a wide range of uses across various fields including nutrition medicines, agriculture and even industry.

Nutritional and Medicinal Value of Moringa Leaves:

Moringa leaves are a powerhouse of nutrients, containing significant amounts of vitamins A, C and E, calcium, potassium and protein. They also possess antioxidant and anti-inflammatory properties, contributing to their medicinal benefits.

Preparation of moringa leaf powder:

Following harvest, the leaflets were cleaned and sorted to remove any broken ones. The leaves are pre-treatment, which included drying and blanching. To prevent browning and maintain the leaves' nutritional value, they were blanched in water for five minutes. The leaves were either cabinet dried at 60°C for 6 hours or shade dried at 28-30°C for 6 days after blanching. Collect the dried moringa leaves and blend it well until desired consistency is achieved.

Preparation of moringa flower powder:

Using a cabinet drier, *Moringa oleifera* flowers were dried. The best method in the food industry for restoring nutritional content is dehydration. Edible parts were extracted from

Moringa after the flowers were detached from the stem ends. To guarantee even drying, the samples were rotated often while being dried in a cabinet dryer set to 65°C until they were crisp or completely dry.

Dehydration of mature pod:

Choose the fully cleaned and surface dried mature moringa pods. Slice the lengthy moringa pods into 2 cm pieces. After two minutes of blanching, spread it out on trays to dry. Use a cabinet dryer set to 55°C to dry the pods. It is used to preparation of curries and sambar.

Moringa seed cake powder:

The seeds are extracted from the pods after harvest. To effectively extract the seeds, this can be done by hand or with the aid of instruments. For the best quality, seeds must be harvested from completely developed pods. To get rid of any contaminants, such dirt or debris, the extracted seeds are further washed.

Oil extraction is frequently the main goal of processing Moringa seeds. The solid residue known as the seed cake is left behind after the seeds are crushed or pressed to release the oil. A sizable amount of the nutrients found in the original seeds are preserved in this cake. The secretion from *Moringa olifera* stems is known as moringa gum. The gum that is expelled from the stem is white at first, but with prolonged exposure, it becomes reddish brown or brownish black. The gum's industrial and pharmaceutical uses are measured as stabilisers, binders and mucoadhesive. In addition, it is valued for its cost-effective, therapeutic and nutraceutical qualities in worldwide.

Moringa seed oil:

Distilled water was used to clean the seed. After that, these were ground and allowed to air dry in the lab. Weighing 10.0g of this, we put it on nicely folded filter paper. Next, the sample-containing filter paper was put into the Soxhlet device. Weighing the filter paper and sample was noted. After measuring out 200 millilitres of the solvent (hexane) with a measuring cylinder, the sample was placed in a 500-millilitre round-bottom flask and heated to 60°C for five hours. The sample was then taken out and placed in an air oven to dry for fifteen minutes at 105°C.

According to Indian Ayurveda, moringa oil is used to treat a variety of illnesses in the indigenous medical system, especially in South Asia, and is said to have antitumor, antipyretic,



antiepileptic, anti-inflammatory, antiulcer, antispasmodic, diuretic, antihypertensive, cholesterol lowering, antioxidant, antibacterial and antifungal properties.

Moringa leaf extract:

Since moringa leaf contains the natural cytokinin zeatin, it is regarded as a regulator of plant growth. Other natural stimulants that help it grow include proteins, amino acids, phenolics, ascorbates, vitamin E and numerous other mineral components.

Application of MLE (Moringa Leaf Extract) is very effective in promoting the growth and developmental responses of plants, causing height, biomass and yield processes in tomato (*Solanum lycopersicum*), such as fruit weight, quantity and quality. Additionally, it plays an effective role in boosting fruit quantity and quality, growth and leaf count.



UNLOCKING THE POWER OF PASSION FRUIT: A MEDICINAL MARVEL

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Introduction

Passion fruit, botanically called *Passiflora edulis*, is recognized for its diverse pharmacological properties that enhance its therapeutic uses and application in home remedies. All parts of the plant, particularly the fruit, offer significant health benefits due to their effects, which include managing diabetes, reducing anxiety, combating tumours, possessing antioxidant qualities, alleviating pain, and providing anti-inflammatory benefits. Moreover, passion fruit contains a variety of chemical compounds, such as essential oils, flavonoids, lipids, and triterpenoids, in addition to aldehydes, ketones, tridecanone, palmitic acid, stearic acid, linoleic acid, quercetin, apigenin, and vitexin. These substances play a crucial role in the pharmacological effects of the plant. The leaves of *P. edulis*, known for their highly appreciated and pleasant taste, are commonly used as sedatives and tranquilizers in the United States and European countries. The peels, which are rich in polyphenols, fibers, and trace elements, have been widely utilized for making wine and tea, cooking dishes, extracting pectin and medicinal ingredients, and processing animal feed. The seeds are edible and high in protein and oil, primarily consisting of linoleic acid, oleic acid, and palmitic acid. In addition to their use as a food item, various pharmaceutical products derived from these ingredients have been developed and are used in folk medicine.

BOTANICAL DESCRIPTION of *Passiflora edulis*

Vernacular Name	Passion fruit, Grenadine, Passionflower, Purple granadilla, purple passion fruit and Grenadilla.
Description & Habitat	<i>Passiflora edulis</i> thrives in tropical and subtropical environments, particularly in mesic to wet areas such as forests, scrub, forest edges, gaps, and riparian zones.
Biology	<i>Passiflora edulis</i> is a perennial vine with tendrils that develop in leaf axils. These tendrils exhibit a red or purple hue when they are young. There are two main varieties of this plant: the purple-fruited type and the yellow-fruited variety.
Plant Description	Most passion flowers are either climbing or sprawling vines that feature grasping tendrils; however, some varieties may also grow as trees or shrubs. These plants can be either herbaceous or woody. Typically, the fruit measures about 6 cm in length and weighs between 60 to 90 grams. The yellow variety tends to have a more vigorous growth habit and usually produces larger fruit compared to the purple variety. The yellow passion fruit contains brown seeds and has a firm, round, shiny shell.
Leaves	The simple leaves are entire or lobed.
Flowers	Most passion flowers are evergreen with dark green leaves and either white or purple blooms. Some passion flowers are suitable only for growing in a conservatory or greenhouse.
Fruits	The yellow <i>passion fruit</i> is 6–12 cm long and 4–7 cm in diameter. The peel is bright yellow, hard, and thick. The seeds are brown.



Purple Passion fruit



Yellow Passion fruit



Flower

NUTRITIONAL COMPOSITION

On behalf of the USDA, the nutritional composition of purple and yellow passion fruit juice has been reported in the Food Composition Database. The data indicates that both purple and yellow passion fruit juices are rich in carbohydrates, vitamin A, vitamin C, minerals, and fiber. Overall, the nutritional content of the purple passion fruit is very similar to that of the yellow variety.

NUTRITIVE VALUE OF PASSION FRUIT PER 100g

Nutrients	Nutritional value per 100g	Nutrients	Nutritional value per 100g
Energy	97 kcal	Thiamine	0.0 mg
Carbohydrate	23.38 g	Vitamin A	1274 IU
Protein	2.20 g	Vitamin C	30 mg
Total fat	0.7 g	Potassium	348 mg
Cholesterol	0.0 g	Calcium	12 mg
Dietary fiber	10.4 g	Iron	1.60 mg
Folates	14 µg	Magnesium	29 mg
Niacin	1.5 mg	Phosphorus	68 mg
Pyridoxine	0.1 mg	Carotene	743 µg
Riboflavin	0.130 mg	Crypto-xanthene	41 µg

PHARMACOLOGICAL ASPECTS ANTI-INFLAMMATORY

The aqueous extract of *Passiflora edulis* leaves, along with butanolic and aqueous fractions, demonstrated significant anti-inflammatory effects in an in vivo model. When administered at doses of 100-1000 mg/kg intraperitoneally, the extract effectively reduced inflammation in carrageenan-induced pleurisy in mice. This extract inhibited leukocyte influx into the pleural cavity and lowered levels of myeloperoxidase, nitric oxide, TNF-alpha, and IL-1beta. It was also effective against pleurisy induced by bradykinin, histamine, and substance P. Comparative experiments showed that *P. edulis* was as effective as dexamethasone in reducing leukocytes and nitric oxide levels while surpassing dexamethasone in suppressing TNF-alpha and IL-1beta. Therefore, *P. edulis* may offer a promising source for new anti-inflammatory therapies similar to existing steroids.

ANTI-HYPERTENSIVE ACTIVITY

The anti-hypertensive effects of both yellow and purple passion fruit products have been demonstrated in spontaneously hypertensive rats. When *P. edulis* peel extract was administered orally, it resulted in reduced hemodynamic parameters, decreased serum nitric oxide levels, and lower blood pressure in these rats. These effects are likely due to the presence of polyphenols such as luteolin, luteolin-6-C-glucoside, quercetin, edulilic acid, ascorbic acid, piceatannol, and anthocyanins. These compounds can modulate nitric oxide and have significant vascular effects. However, the precise mechanisms and specific compounds responsible for these effects require further investigation.

HEPATOPROTECTIVE AND LUNG-PROTECTIVE ACTIVITIES

Oral administration of purple passion fruit peel extract demonstrated hepatoprotective effects against liver injury induced by chloroform (1 mmol) in rats. It also exhibited notable hepatoprotective activity against CCl₄-induced hepatotoxicity. In a study with mice, the daily administration of passion fruit juice for 15 days protected against ethanol-induced liver injury by reducing levels of AST and ALT in the liver, as well as alleviating inflammation and oxidative stress. Furthermore, passion fruit seed extract was shown to prevent non-alcoholic fatty liver disease by improving liver hypertrophy and hepatic histology in rats fed a high-fat diet. In a model of pulmonary fibrosis in C57BL/6J mice induced by bleomycin, the administration of passion fruit peel extract significantly reduced body weight loss and mortality rates. It also decreased the number of inflammatory cells, including macrophages, lymphocytes, and

neutrophils, reduced MPO activity, and restored the depletion of SOD activity caused by bleomycin.

ANTIOXIDANT

The leaves of *Passiflora edulis* exhibit antioxidant activity. Hydro-alcoholic extracts from *P. edulis* leaves were tested in both in-vitro and ex-vivo assays. The antioxidant activity of the *P. edulis* leaf extract showed a significant correlation with its polyphenol content. Additionally, *P. edulis* was found to reduce ex vivo iron-induced cell death, which was measured by lactate dehydrogenase leakage, and it effectively protected against protein damage caused by iron and glucose. The antioxidant capacity of *P. edulis* leaves was also evaluated against DPPH radicals and several reactive oxygen species, including superoxide radicals, hydroxyl radicals, and hypochlorous acid. This capacity was found to be concentration-dependent; however, a pro-oxidant effect was observed with hydroxyl radicals. These findings indicate that *P. edulis* leaf extract possesses potent in-vitro and ex-vivo antioxidant properties, suggesting it may serve as a potential source of natural antioxidants. Further research is necessary to explore the possible use of *P. edulis* extract in preventing conditions such as diabetes mellitus and neurodegenerative diseases, where oxidative stress-induced protein damage plays a significant role.

ANTITUMOR ACTIVITY

Most of the pharmacological research has focused on the antitumor activity of *P. edulis*. In vitro studies have demonstrated that various extracts of *P. edulis* exhibit cytotoxicity against HepG2, MCF-7, Caco-2, CCRF-CEM, CEM/ADR5000, and p53(-/-) cell lines. It was found that the higher content of polyphenols and polysaccharides in the ethanolic extract may be related to the inhibition of matrix metalloproteinases MMP-2 and MMP-9. In vivo, the ethanol extract of yellow passion fruit inhibited tumor growth with an inhibition rate of 48.5% and increased the lifespan of male Balb/c mice inoculated with Ehrlich carcinoma cells by nearly 42%. This effect could be attributed to the presence of medium- and long-chain fatty acids, such as lauric acid. Both oral (P.O.) and intraperitoneal (I.P.) administration of the polysaccharide resulted in the inhibition of sarcoma 180 tumor growth, with an inhibition ratio ranging from 40.59% to 48.73%.

ANTIDIABETIC ACTIVITY

Numerous studies have highlighted the antidiabetic effects of *Passiflora edulis*, including its peel, seeds, and juice. For example, a daily dose of 580 mg/kg of passion fruit juice over 30

days significantly reduced glucose levels in the offspring of diabetic rats. Likewise, extracts from passion fruit seeds and leaves lowered blood glucose in db/db mice and alloxan-induced diabetic Wistar rats. Additionally, pectin from the fruit peel reduced blood glucose levels in alloxan-induced diabetic rats when administered at doses of 0.5 to 25 mg/kg for 5 days. Consumption of peel flour increased insulinotropic hormones, enhancing insulin sensitivity in obese rats and preventing insulin resistance from a low-fructose diet. The flavonoid-rich leaf extract also offers protective benefits against diabetic complications.

ANXIOLYTIC-LIKE ACTIVITY

Extracts of *P. edulis*, such as butanolic, methanol, ethanol, hydro-ethanol, and aqueous extracts, have shown anxiolytic-like effects in various tests. The aqueous extract at doses of 50, 100, and 150 mg/kg demonstrated these effects in the elevated plus-maze and inhibitory avoidance tests in rats. Notably, the aqueous extract did not disrupt memory in a rat open-field test, while diazepam did. The methanol extract at 75 mg/kg showed anxiolytic activity in mice, but higher doses of 125 mg/kg had no significant effect, whereas doses of 200 and 300 mg/kg produced mild sedation. Further, hydro-ethanol extracts at 50, 100, and 150 mg/kg, as well as spray-dried powders at 400 and 800 mg/kg, also exhibited anxiolytic activity in mice. These effects are likely due to the presence of several flavonoids, including isoorientin, orientin, luteolin, apigenin, and chrysin.

ANALGESIC ACTIVITY

Studies have shown that n-butanol extracts from the leaves of *Passiflora edulis* exhibit dose-dependent analgesic activity in a thermal stimulation pain model. In tests involving acetic acid-induced writhing, formalin-induced paw licking, and response latency in the Eddy's hot plate test, the polysaccharide derived from the dried fruit of *P. edulis* significantly reduced writhing and paw licking caused by acetic acid and formalin, respectively. However, it did not produce a significant increase in reaction time during the hot plate test, suggesting that the analgesic activity of the polysaccharide is related to peripheral mechanisms.

Conclusion

Passion fruit is well-known for its appealing nutritional and sensory qualities, benefiting consumers' health worldwide. Its secondary metabolites have gained attention for their health benefits and economic value, making them valuable in nutrition, cosmetics, and medicine. Different types of passion fruit have varying chemical compositions. Yellow passion fruit

typically has higher water content and lower nutritional components, while purple passion fruit is richer in vitamin C, vitamin A, fiber, and calcium. Additionally, different parts of the plant, such as leaves, peels, and pulp, contain diverse bioactive components. Yellow passion fruit offers higher pectin in its peels and more carotenoids, quercetin, and kaempferol in its pulp, while purple passion fruit is distinguished by its high anthocyanin content. Notably, the peels, which account for about 50% of the fruit, hold the potential for functional ingredients due to their active compounds. Extracts from various parts of the fruit have demonstrated pharmacological activities, such as antioxidant, anti-inflammatory, and anti-diabetic effects, making them useful in phytotherapeutic remedies. Toxicity studies suggest that a rational daily dose of passion fruit is likely safe for consumption. Overall, passion fruit may help manage inflammatory and neurological diseases and could play a role in preventing chronic conditions like hypertension and hyperlipidemia.

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REAPING THE FUTURE: RECENT ADVANCEMENTS IN PLANT BREEDING IN INDIA

Article ID: AG-VO5-I06-23**¹Sakthi Anand, M.K.¹, ^{2*}V. Krishnan, ³Maddu. Geethanjali, ³R. Praveen, ³K. Preetha,****³Adavi Lakshmi Nikhil and ³A. Shivada**

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Introduction

Over the last five years, India's agricultural sector has witnessed a dynamic transformation, propelled largely by innovations in plant breeding. Faced with the dual challenges of feeding a growing population and sustaining agricultural productivity in the face of climate volatility, the country has increasingly turned to science-driven breeding programs. These advancements are not limited to yield enhancement alone; they encompass a broader mission—improving the nutritional quality of crops, enhancing resilience to abiotic and biotic stresses, and ensuring sustainable farming practices that are inclusive of small and marginal farmers. The period from 2020 to 2025 has been particularly significant, marked by the widespread adoption of modern biotechnological tools such as marker-assisted selection (MAS), genomic selection (GS), and CRISPR-based genome editing. These tools have enabled breeders to develop improved crop varieties at a much faster pace compared to traditional methods. Additionally, strategic investments in phenomics, bioinformatics, and speed breeding have further accelerated crop improvement pipelines.

Government-supported initiatives, such as those by the Indian Council of Agricultural Research (ICAR), State Agricultural Universities (SAUs), and public-private partnerships, have played a crucial role in bringing cutting-edge research from laboratories to farmers' fields. Notably, several climate-resilient varieties of rice, wheat, millets, and pulses have been released

to help mitigate the impact of erratic rainfall, rising temperatures, and soil salinity. At the same time, India has emerged as a global leader in biofortification—developing and deploying crop varieties with enhanced micronutrient content. These include zinc-rich rice, iron-enriched pearl millet, and provitamin-A fortified maize, which are now cultivated across multiple agro-climatic zones, offering both nutritional and economic benefits to farming communities. This period also saw the convergence of traditional breeding wisdom with next-generation technologies, reflecting a holistic and sustainable approach to crop improvement. As India marches toward its vision of "Atmanirbhar Krishi" (self-reliant agriculture), plant breeding continues to serve as the cornerstone of food and nutrition security, climate adaptation, and agricultural innovation.

Genomics-Driven Precision Breeding

The advent of genomics-assisted breeding has revolutionised traditional plant breeding methods in India. Institutions like the Indian Council of Agricultural Research (ICAR) and the Indian Agricultural Research Institute (IARI) have harnessed molecular marker technologies to expedite the development of superior crop varieties. Marker-Assisted Selection (MAS) has been instrumental in developing drought-tolerant rice varieties such as DRR Dhan 58 and rust-resistant wheat varieties like HD 3226. Genome-wide association studies (GWAS) and quantitative trait loci (QTL) mapping have further facilitated the identification of genes responsible for salinity tolerance, earliness, and disease resistance across major crops.

Embracing Genome Editing Technologies

India's regulatory approval for gene-edited crops in 2022 marked a significant milestone in agricultural biotechnology. The Ministry of Science and Technology issued Standard Operating Procedures (SOPs) for the regulatory review of genome-edited plants under SDN-1 and SDN-2 categories, exempting them from certain GMO regulations (Press Information Bureau, 2022). This move has enabled researchers to develop CRISPR-edited crops with improved traits. For example, scientists at the Indian Institute of Horticultural Research (IIHR) in Bengaluru have successfully developed CRISPR-edited tomato lines with extended shelf life. Additionally, ongoing research is focusing on gene editing in rice and groundnut to enhance abiotic stress tolerance and improve oil quality (Sharma *et al.*, 2025).

The *Standard Operating Procedures for Genome-Edited Plants*, published by the Department of Biotechnology, comprehensively outlines the scientific basis, research initiatives, and regulatory framework governing genome-edited plants in India.

First Genome-Edited Rice Varieties

India has achieved a breakthrough in genome editing with the release of its first genome-edited rice varieties by the Indian Agricultural Research Institute (IARI). These varieties, Pusa DST Rice 1 and DRR Dhan 100 (Kamala), were developed using CRISPR-Cas genome editing technology to enhance yield, drought tolerance, and nitrogen-use efficiency and were officially released on May 4, 2025, by Union Agriculture Minister Shivraj Singh Chouhan.



IARI announced the development of two gene-edited varieties of rice. File | Photo Credit: ANI (The Hindu article 69541542, May 06, 2025)

Key Features of the Genome-Edited Rice Varieties

- **DRR Dhan 100 (Kamala):** Developed from the popular Samba Mahsuri (BPT 5204) variety, this genome-edited line targets the Cytokinin Oxidase 2 (CKX2) gene, increasing grain number per panicle. It matures 15-20 days earlier than its parent variety, reducing water consumption and methane emissions while improving yield by 19 Per cent.
- **Pusa DST Rice 1:** Developed from MTU1010 (*Cotondora Sannalu*), this variety was edited to enhance drought and salt tolerance by modifying the DST (Drought and Salt Tolerance) gene. It has shown 9.66 per cent yield superiority under salinity stress and 14.66 Per cent improvement under alkalinity conditions.

Significance of the Breakthrough

- These genome-edited rice lines were tested in multi-location field trials under the All India Coordinated Research Project on Rice (AICRPR) during 2023 and 2024,

demonstrating higher yields and improved stress tolerance.

- The varieties are free from foreign DNA, making them equivalent to conventionally bred mutants, and have been approved by India's biosafety regulatory committees.
- Their early maturity and strong lodging resistance make them ideal for cultivation across multiple states, including Andhra Pradesh, Telangana, Karnataka, Tamil Nadu, Odisha, Bihar, and West Bengal.

This marks a historic milestone in India's agricultural biotechnology, paving the way for sustainable and climate-resilient rice production.

Developing Climate-Resilient Crop Varieties

Climate change poses a significant threat to Indian agriculture, necessitating the development of crop varieties that can withstand extreme weather conditions. In response, Indian scientists have developed several climate-resilient crop varieties. For example, the National Rice Research Institute (NRRI) in Odisha has developed rice varieties like CR Dhan 108, CR Dhan 810, and CR Dhan 416, which exhibit enhanced tolerance to high temperatures, drought, and salinity, respectively. Similarly, the Indian government aims to bring 60 per cent of the total wheat area under climate-resistant varieties in the upcoming rabi season to mitigate the impacts of El Niño.

Advancements in Biofortification

Addressing micronutrient deficiencies through biofortification has been a focal point of India's agricultural strategy. The Indian Council of Agricultural Research (ICAR) has developed 87 biofortified cultivars across 16 crops, including zinc-enriched rice (CR Dhan 315), protein and iron-rich wheat (HD 3298), and lysine and tryptophan-enhanced maize hybrids. Since 2020, India has made remarkable progress in biofortification to tackle micronutrient deficiencies. The Indian Council of Agricultural Research (ICAR) has developed multiple biofortified cultivars across various crops, integrating them into national nutrition programs like POSHAN Abhiyaan (Yadava *et al.*, 2022).

Key Achievements Since 2020:

- 2020: 17 micronutrient biofortified varieties were introduced on World Food Day (October 16, 2020).
- 2021: 35 special trait varieties were dedicated to the nation by the Prime Minister of India on September 28, 2021.

- 2020-21: India achieved an all-time high food grain production of 308.65 million tonnes, largely due to high-yielding biofortified varieties.

Notable Biofortified Crops:

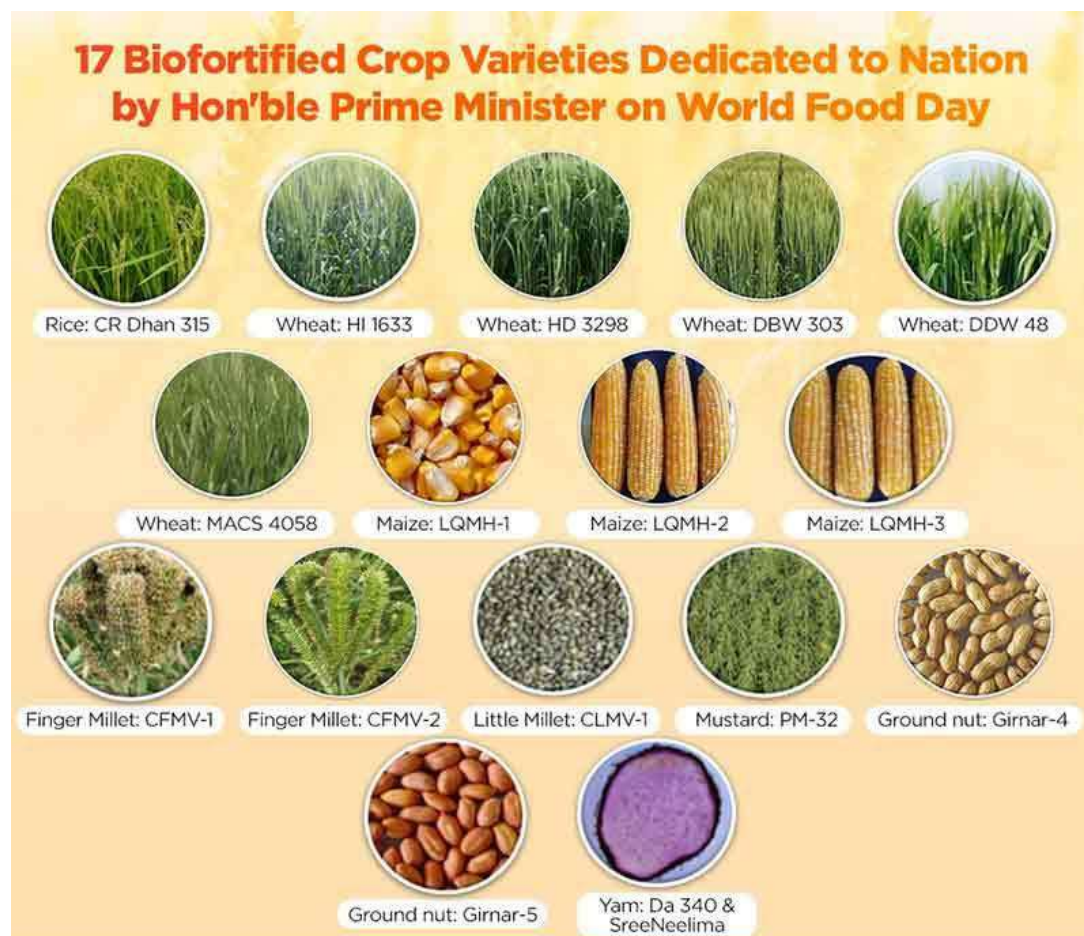
- Zinc-enriched rice (CR Dhan 315)
- Protein and iron-rich wheat (HD 3298)

India has developed several lysine and tryptophan-enhanced maize hybrids through biofortification (Krishi Jagran. (2024, September 6)). Some notable ones include:

- Vivek QPM 9 – Developed by ICAR-Vivekananda Parvatiya Krishi Anusandhan Sansthan, Almora. It contains 4.19 Per cent lysine and 0.83 Per cent tryptophan in protein.
- Pusa HM4 Improved – Developed by ICAR-Indian Agricultural Research Institute, New Delhi. It has 3.62 Per cent lysine and 0.91 Per cent tryptophan.
- Pusa HM8 Improved – Designed for regions like Maharashtra, Karnataka, Andhra Pradesh, Telangana, and Tamil Nadu. It contains 4.18 Per cent lysine and 1.06 Per cent tryptophan.
- Pusa HM9 Improved – Tailored for Bihar, Jharkhand, Odisha, Eastern Uttar Pradesh, and West Bengal.

The biofortified varieties are about three times more nutritious than the traditional varieties.

- The rice variety CR DHAN 315 has excess zinc.
- The wheat variety HD 3298 is enriched with protein and iron.
- DBW 303 and DDW 48 are rich in protein and iron.
- The maize hybrid varieties 1, 2 and 3 are enriched with lysine and tryptophan.
- The finger varieties of Millet CFMV 1 and 2 are rich in calcium, iron and zinc.
- The CCLMV1 variety of small millet is rich in iron and zinc.
- The Pusa Mustard 32 is enriched with low Erucic Acid.
- Girnar 4 and 5 varieties of peanuts are rich in increased Oleic Acid.
- Yam's Shri Neelima and DA 340 varieties are enriched with anthocyanin.



(Manorama Year book,2020)

Integration of Digital Tools and Speed Breeding

India's adoption of digital technologies in crop breeding is backed by several scientific studies and advancements:

- Speed Breeding and AI Integration:** A study published in Molecular Biology Reports discusses how speed breeding combined with artificial intelligence is accelerating the development of climate-smart crops. It highlights how controlled environments and AI-driven selection are optimizing breeding cycles (Rai, K.K, 2022).
- AI in Plant Breeding:** A white paper by Inari outlines how artificial intelligence is transforming plant breeding by analyzing genetic patterns and making precise predictions. AI is helping researchers identify ideal genetic traits for improved crop resilience and yield.

- **High-Throughput Phenotyping and Speed Breeding:** A report from Junagadh Agricultural University details how controlled environments, genetic advancements, and phenotyping techniques are expediting crop improvement. It discusses trait selection, breeding strategies, and environmental stress tolerance (Vala *et al.*, 2023).

Collaborative Efforts and Farmer Adoption

Public-private partnerships have played a crucial role in disseminating improved crop varieties to farmers. Collaborations between ICAR and seed companies like Nuziveedu Seeds and Kaveri Seeds have expedited the release of superior hybrids. International organisations such as the International Rice Research Institute (IRRI), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the International Maize and Wheat Improvement Centre (CIMMYT) continue to support regional crop development efforts. Participatory Plant Breeding (PPB) programs also involve farmers directly in the selection process, ensuring that new varieties meet local needs and preferences.

Conclusion

India's advancements in plant breeding over the past five years underscore a commitment to leveraging science and technology to address pressing agricultural challenges. Through the integration of genomics, genome editing, climate resilience, biofortification, and digital tools, Indian agriculture is poised to enhance productivity, ensure food and nutritional security, and build resilience against climate change. These innovations benefit farmers and contribute to the broader goal of sustainable and inclusive agricultural development.

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MAJOR INSECT PESTS OF RICE IN THE KOSI REGION OF BIHAR

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Introduction

The Kosi region of Bihar, encompassing districts such as Saharsa, Supaul, and Madhepura, lies in the floodplains of the Kosi River and is known for its fertile alluvial soil and abundant rice cultivation. The Kosi region of Bihar is a significant rice-producing area, with rice being a staple crop grown throughout the year. The region contributes significantly to Bihar's total rice area, which is approximately 3.2 million hectares. The warm, humid climate and extensive irrigation systems also create ideal conditions for a wide range of insect pests. The Kosi region, with its unique agro-climatic conditions, provides a conducive environment for the proliferation of several rice insect pests. These pests significantly affect the growth, development, and yield of rice crops, leading to considerable economic losses. Understanding the major insect pests prevalent in this region and their management is crucial for sustainable rice production.

1. Yellow Stem Borer (*Scirpophaga species*)

Among the most destructive pests, stem borers are a perennial problem. The Yellow Stem Borer (YSB) is particularly widespread and economically significant in Bihar. These lepidopteran larvae bore into the rice stems, causing characteristic damage. In young plants, the central shoot dries up and can be easily pulled out this symptom is known as "Dead heart" where as in older plants, it causes "White ear-head" In this, after panicle emergence the panicle dries

up and becomes sterile, appearing bleached white.

2. Brown Planthopper (*Nilaparvata species*)

This is a major insect pest, particularly in irrigated rice ecosystems with intensive cultivation. BPH sucks sap from the phloem vessels, leading to wilting and drying of plants, a symptom known as "hopper burn." Besides direct damage, BPH is also a vector for devastating viral diseases like rice grassy stunt and ragged stunt.



YELLOW STEM BORER



SEMILOOPER



GUNDHI BUG



GRASSHOPPER

3. Rice Leaf Folder (*Cnaphalocrocis species*)

Rice leaf folder is a leaf-folding and leaf-feeding caterpillar that attacks during tillering and booting stages. Caterpillars fold a rice leaf around them and attach the leaf margins with silk strands. They feed inside the folded leaf creating longitudinal white and transparent streaks on the blade. This damage reduces the photosynthetic area of the plant, leading to stunted growth and reduced grain filling.

4. Rice Hispa (*Dicladispa species*)

Both adults and grubs cause damage by scraping the leaf surface, leading to characteristic white parallel streaks. Generally, the plants are affected in the young stage.

5. Gundhi Bug (*Leptocorisa species*)

It is known as the rice earhead bug, the gundhi bug is a serious threat during the milky and dough stages of grain development. Both nymphs and adults feed on the developing grains, sucking out the milky sap. This results in "chaffy grains" or partially filled grains, reducing both the quality and quantity of the harvest. A characteristic foul odor is emitted by these bugs.

6. Rice grasshopper

Adult and nymph stages of rice grasshopper constitute a significant threat to crops like rice by chewing plant tissues primarily at the leaves and stems. This can cause mild to severe damage, leading to stunted growth, reduced yields, and plant death in heavy infestations.

Minor insect pest

While the above are the primary concerns, other pests can also cause sporadic damage, and their status can shift with changing agricultural practices and climate. These include gall Midge, green leaf hopper, case worm, semilooper and rice horned caterpillar.

Conclusion

Rice cultivation in the Kosi region is vital but threatened by various insect pests. Through an integrated approach including cultural, mechanical, biological, and chemical strategies, pest populations can be managed effectively. Educating farmers about timely pest monitoring and sustainable control methods is essential to ensure food security and improved yields.

ROLE OF BACTERIAL PATHOGENS FOR PEST MANAGEMENT

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Introduction

Control of insect pests in agriculture is mainly achieved using chemical insecticides. To mitigate the crop loss by pests, farmers often resort to frequent application of chemical pesticides in large quantities. In spite of heavy insecticide application, the crop loss increases due to various reasons like development of resistance, pest resurgence and pest replacement besides negatively influencing environment and human health by way of leaving toxic residues. Excessive use of synthetic pesticides accounts for around 39 % of food crop losses throughout the world (Sharma et al. 2019). Hence there is a need to evolve eco-friendly management strategies. Bacteria are one of the most exploited microbial agents of insect pest management programmes. The biological control paradigm changed, when the potential of entomopathogenic bacteria was discovered, especially species belonging to the genus *Bacillus* (Mampallil *et al.*, 2017).

The discovery of new *Bacillus thuringiensis* (Bt) strains showing high toxicity against specific insects at a competitive level compared to conventional insecticides in terms of efficacy and costs of production. Besides the entomopathogenic bacteria, there exist certain bacteria that can effectively colonise plants by occupying different sites such as roots, leaves or as inter or intracellular colonisers. The control of pests by entomopathogenic and plant associated bacteria

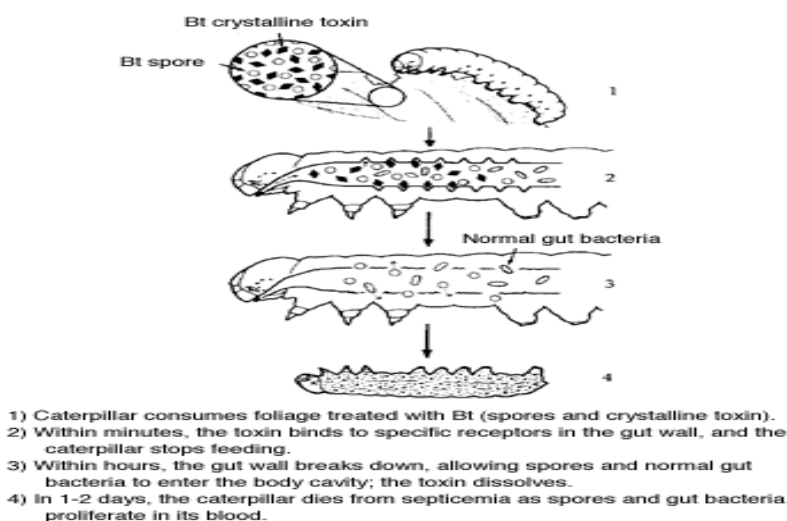
is an alternative that may contribute to reduce or eliminate the use of pesticides (Gunstone et al., 2021).

Bacillus thuringiensis (commonly known as 'Bt') is an insecticidal bacterium, marketed worldwide for control of many important plant pests - mainly caterpillars of the Lepidoptera (butterflies and moths) but also mosquito larvae (Domínguez et al., 2020). Bt products represent about 1% of the total 'agrochemical' market (fungicides, herbicides and insecticides) across the world (Gunstone et al., 2021). The commercial Bt products are powders containing a mixture of dried spores and toxin crystals. They are applied to leaves or other environments where the insect larvae feed. The toxin genes have also been genetically engineered into several crop plants. The method of use, mode of action, and host range of this biocontrol agent differ markedly from those of *Bacillus popilliae*.

Mode of Action

The toxic crystal Bt protein in commercial formulations is only effective when eaten by insects with a specific (usually alkaline) gut pH and the specific gut membrane structures required to bind the toxin. Not only must the insect have the correct physiology and be at a susceptible stage of development, but the bacterium must be eaten in sufficient quantity. When ingested by a susceptible insect, the protein toxin damages the gut lining, leading to gut paralysis. Affected insects stop feeding and die from the combined effects of starvation and tissue damage. Bt spores do not usually spread to other insects or cause disease outbreaks on their own as occurs with many pathogens (Sharma et al. 2019).

Action of *Bacillus thuringiensis* var. *kurstaki* on caterpillars



Bt toxin and their classification

Gene	Crystal shape	Protein size(kDa)	Insect activity
cry I subgroups: A(a), A(b), A(c), B, C, D, E, F, G)	bipyramidal	130-138	lepidoptera larvae
cry I subgroups: A(a), A(b), A(c), B, C, D, E, F, G)	bipyramidal	130-138	lepidoptera larvae
cry II (subgroups A, B, C)	cuboidal	69-71	lepidoptera and diptera
cry III (subgroups A, B, C)	flat/irregular	73-74	coleoptera
cry IV (subgroups A, B, C, D)	bipyramidal	73-134	diptera
cry V-IX	Various	35-129	various

Most of the insect pathogenic bacteria occur in the families Bacillaceae, Pseudomonadaceae, Enterobacteriaceae, Streptococcaceae and Micrococcaceae; in the order Ricettsiales and class Mollicutes (Tanada and Kaya, 1993). However, members of Bacillaceae, particularly *Bacillus* spp. have received maximum attention. Members of the family Bacillaceae produce endospores and are gram-positive motile or non-motile rods. The insect pathogens occur in the genera *Bacillus* and *Clostridium*. The genus *Bacillus* contains some of the most important entomopathogenic species, among which *B. thuringiensis* Berliner (Bt) has been most widely exploited as a microbial control agent. Bt is motile, gram positive, spore forming bacterium and in addition to endospores, produces a proteinaceous parasporal crystal in the sporangium at the time of sporulation. *B. thuringiensis* is widely distributed in nature and is being discovered repeatedly from different geographical areas and habitats frequented by various complex of class Insecta.

The first major commercial product called Dipel, an isolate of *Bt kurstaki* was produced by Abbott Laboratories in 1970. Presently *kurstaki* HD-1 based products are registered for nearly 30

crops against more than 100 insect pest species worldwide and several million kilograms are produced in USA and other countries (Lee et al., 1998). Similarly, a number of Bt screening trials have identified strains with proteins having a wide host range among lepidopteran, coleopteran and dipterans insect pests. *Bt israelensis* is now a major commercial product for the control of mosquitoes and black flies which are human disease vectors worldwide. Recent X-ray crystal structure of Bt Tenbrionis Cry IIIA protein has opened new vistas for protein engineering and design of Bt insecticides (Sharma et al. 2019).

Bt products available in India

Bt variety	Trade name	Target pest	Crop	Manufacturer
<i>Bt kurstaki</i>	Halt	DBM and caterpillars	Cabbage	Wockhardt Ltd.,
<i>Bt kurstaki</i>	Biolep	Cotton bollworms	Cotton	Biotech international Ltd., New Delhi
<i>Bt kurstaki</i>	Bioasap	Cotton bollworms	Cotton	Biotech international Ltd., New Delhi
<i>Bt kurstaki</i>	Delifin WG	Cotton bollworms, tobacco caterpillar	Cotton, castor	M/s Sandoz India Ltd., Bombay
<i>Bt kurstaki</i>	Dipel 8 L	Cotton bollworms, Fruit borers	Cotton, tomato, okra, brinjal,	Lupin agrochemicals Pvt., Bombay
<i>Bt galleriae</i>	spicturn	<i>H. a</i> leaf folder, tobacco caterpillar, DBM	Cotton, rice, cabbage, cauliflower and chilies	Tuticorin alkali chemicals & fertilizers Ltd., Chennai
<i>Bt galleriae</i>	Biobit	Lepidopterous caterpillars	Several	Rallis India Ltd., Bangalore

Advantages of using biopesticides

- Bt' are usually inherently less toxic than conventional pesticides.

- Bt' generally affect only the target pest and closely related organisms, in contrast to broad spectrum, conventional pesticides that may affect organisms as different as birds, insects and mammals.
- Bt' often are effective in very small quantities and often decompose quickly, thereby resulting in lower exposures and largely avoiding the pollution problems caused by conventional pesticides
- When used as a component of Integrated Pest Management (IPM) programs, Bt' can greatly decrease the use of conventional pesticides, while crop yields remain high.
- To use Bt' effectively, however, users need to know a great deal about managing pests.

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SOIL ENHANCERS – TYPES, ORGANIC AND INORGANIC SOIL ENHANCERS, ROLE & BENEFITS

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Introduction

Across the nation, vast areas of land lie degraded and polluted. Some are in isolated regions, complicating restoration efforts, while others suffer from limited funding or immense scale, making cleanup financially unfeasible (Pichtel, 2016). Affordable, low-energy solutions are urgently needed to rehabilitate these sites. One such approach involves soil enhancers—an economical, in-situ method for restoring and repurposing damaged or contaminated terrain (Bolan et al., 2011). This discussion highlights byproducts from other industries that, when applied to soil, offer ecological benefits. Common enhancers include urban biosolids, livestock waste, beet lime, wood ash, coal byproducts like fly ash (Pandey & Singh, 2010), farm waste, lime neutralizers, processed biosolids (Singh & Agrawal, 2008), composted farm residues (Diacono & Montemurro, 2010), and conventional fertilizers. When used correctly, these additives minimize contamination risks by blocking exposure routes and reducing pollutant mobility (Aciego Pietri & Brookes, 2008).

They also rejuvenate soil by balancing acidity, boosting organic content, enhancing moisture retention (Lehmann & Joseph, 2015), reviving microbial life, and easing soil compaction (Edmeades, 2003). Thus, soil enhancers enable the remediation, replanting, and revitalization of Superfund sites, mining zones, landfills, and industrial areas such as refineries, smelters, and factories. These locations often face challenges like:

Toxicity: Heavy metals harm plants, soil organisms, and microbes (Bolan et al., 2011).

pH Imbalance: Extreme acidity or alkalinity disrupts fertility and mobilizes harmful elements (Qadir et al., 2007).

Excess Sodium/Salts: Degrades soil structure and plant health (Qadir et al., 2007).

Poor Physical Properties: Compaction and texture issues hinder water absorption and root growth (Diacono & Montemurro, 2010).

Nutrient Deficiencies/Overload: Low levels of zinc or manganese stunt growth, while excess amounts become toxic (Edmeades, 2003).

Treatment Side Effects: Some remedies may limit nutrient availability, requiring supplemental fertilization (Cherr et al., 2006).

Additionally, soil enhancers can aid in breaking down volatile pollutants, allowing vegetation to thrive again (Aciego Pietri & Brookes, 2008).

2. SOIL ENHANCERS

Enhancers are materials mixed into soil to improve its quality (Pichtel, 2016). They rehabilitate eroded or mismanaged land, enhance poor soils, and maintain optimal soil health (Diacono & Montemurro, 2010). Numerous products can be employed for soil management (Lehmann & Joseph, 2015).

DEFINITION

A soil enhancer is any substance incorporated into soil to refine its physical traits, such as moisture retention, permeability, drainage, aeration, and texture (Pandey & Singh, 2010). The aim is to foster a healthier root environment. For maximum effect, enhancers must be evenly blended into the soil—merely layering them reduces efficacy and obstructs air, water, and root movement (Edmeades, 2003).

3. CHARACTERISTICS OF SOIL ENHANCERS

- They are natural and synthetic
- Absorbs water rapidly
- Leave and manures are also natural products
- Compost is made from decomposing materials fertilizers and soil

4. ROLE & BENEFITS OF SOIL ENHANCERS

Improve soil's physical, chemical, and biological attributes (Bolan et al., 2011). Adjust pH in acidic or alkaline soils (Qadir et al., 2007). Boost water retention in arid, sandy soils while improving absorption and drainage (Lehmann & Joseph, 2015). Foster a thriving habitat for

beneficial microbes and earthworms (Aciego Pietri & Brookes, 2008). Enhance soil structure, aeration, and ecosystems (Diacono & Montemurro, 2010). Rebuild damaged soils or enrich nutrient-poor land (Singh & Agrawal, 2008). Supply vital nutrients for healthier, more productive plants (Cherr et al., 2006). Counteract soil compaction, increasing pore space (Edmeades, 2003). Elevate fertility and sustain soil vitality (Pichtel, 2016).

5. CATEGORIES OF SOIL ENHANCERS

Soil enhancers can be categorized using two main approaches: their source and their makeup. Regarding their source, these materials may be either artificially manufactured or naturally found. When considering their composition, soil enhancers materials include various types of substances.

i. Organic Enhancers

Derived from living sources (plants/animals), these improve water retention, soil structure, microbial activity, and aeration while reducing hardness and crusting (Diacono & Montemurro, 2010). Common options include:

a) Compost: Decomposed organic waste that enriches soil with carbon, nutrients (N, P, K, Mg), and microbes while suppressing pathogens (Bolan et al., 2011).



b) FYM: A nutrient-rich mix of animal waste and bedding that enhances soil health across all soil types (Edmeades, 2003).



c) **Green Manures:** Crops plowed into soil to boost organic content, aeration, and fertility (Cherr et al., 2006).



d) **Sewage Sludge:** Treated organic waste used cautiously in farming due to potential contaminants (Singh & Agrawal, 2008).



e) **Crop Residues:** Crop residues refer to the remaining plant parts in agricultural fields or orchards after crop harvesting. These include stems (such as stalks and stubble), leaves, and seedpods. They serve as a valuable source of organic matter that can be returned to the soil, promoting nutrient recycling and enhancing the soil's physical, chemical, and biological characteristics (Gupta et al., 2023). Incorporating crop residues into the soil contributes to improved nutrient cycling, better soil and water conservation, and increased yields in subsequent crops (Singh et al., 2024)



f) Peat Moss: Peat moss is composed of partially decomposed plant material or organic matter that accumulates in peatlands, bogs, and moorlands. It forms under acidic and oxygen-poor (anaerobic) conditions, which slow down the decomposition process. Peat moss is beneficial for enhancing soil structure, particularly by boosting its ability to retain moisture (Yu et al., 2023)



g) Humates: Humates are naturally occurring materials derived from ancient organic soils or oxidized lignite, a coal-like substance found near lignite deposits. Unlike peat, humates are fully decomposed or mineralized, making their nutrients readily accessible to plants. They can contain up to 35% humic acids, which aid in dissolving nutrients and enhancing their availability for plant uptake (Sohail et al., 2025)

h) Biochar: Biochar is a solid, fine-grained, black carbon-rich material produced through the slow pyrolysis of biomass, typically derived from agricultural or forestry sources. Its high surface area, negative charge, and dense charge capacity make it effective at adsorbing cations and facilitating nutrient retention and exchange within the soil, benefiting both microbes and plant roots. Biochar helps stabilize both added biomass and native soil organic matter (SOM), thereby improving soil aeration, enhancing microbial activity, and immobilizing nitrogen. These combined effects contribute to the reduction of major greenhouse gas emissions such as CH₄, CO₂, and N₂O (Pandiyan et al., 2024)



ii. INORGANIC SOIL CONDITIONERS:

Inorganic soil conditioners are materials that may be mined, derived as industrial by-products, or synthetically manufactured. They can occur naturally or be artificially produced. Mineral-based inorganic conditioners include substances like gypsum, lime, pyrites, crushed stone, fly ash, sulfur, zeolites, and phosphogypsum. Synthetic conditioners encompass water-soluble polymers designed to stabilize clay, hydrogel polymers, and synthetic binding agents such as anionic and catalytic polymers, as well as non-viable polymers. The use of inorganic soil conditioners aims to enhance the physical structure of soil, thereby enabling more efficient use of soil and water resources. These soluble conditioners interact physically and chemically with soil components, particularly clay minerals. Applying various conditioners such as VAMA, Krilium, PVA, and Hygromull (a urea-formaldehyde-based conditioner) can lead to better soil aggregation, increased porosity and hydraulic conductivity, reduced bulk density, improved infiltration and permeability, and greater water retention within the soil profile .

1) MINERAL CONDITIONERS

Mineral conditioners are applied to improve or restore problematic soils. Common examples include gypsum, lime, sulfur, crushed rocks, and dolomite.

a) Gypsum:

Gypsum serves as a moderately soluble source of essential nutrients such as calcium and sulfur, contributing to overall plant health and growth. One of its key benefits is its ability to replace exchangeable sodium on soil cation exchange sites, making it particularly effective for reclaiming sodic soils. It is also useful in treating saline patches and hard alkali layers by softening and breaking them apart. In soils with low cation exchange capacity, gypsum supplies calcium and enhances water infiltration, especially in compacted or puddled soils. Additionally, gypsum improves the soil's physical, chemical, and biological characteristics, helping to reduce erosion and minimize nutrient runoff, especially phosphorus into surface waters Norton (2008).



b) Lime

Lime refers to calcium-based inorganic compounds, mainly composed of calcium oxides and hydroxides, and typically contains 75–95% calcium carbonate (CaCO_3). It is primarily used to correct the pH in highly acidic soils by increasing soil alkalinity. Acting as a calcium source, lime helps raise the soil pH, making it particularly beneficial for soils with pH levels below 6.0. In such acidic conditions, the soil's capacity to absorb nutrients, including those provided by fertilizers, is reduced, and lime helps to restore nutrient availability by neutralizing the acidity.

**c) Fly Ash:**

Fly ash is a by-product generated from thermal power plants and is utilized both as a soil amendment and a source of plant nutrients. It plays a significant role in enhancing soil fertility and boosting crop productivity. Fly ash contributes to better crop growth and higher yields, particularly in nutrient-deficient soils, by improving the availability of both macro and micronutrients. Additionally, it is used in the development of an innovative soil conditioner known as "Biosil".

**2) OTHER MINERAL CONDITIONERS:**

Materials such as limestone, dolomite, crushed rock, elemental sulfur, and other calcium- and/or magnesium-rich products are commonly used to enhance the physical structure of

degraded or problematic soils. These amendments are typically applied in large quantities, often several tons per acre, to achieve significant improvements.

a) Synthetic Binding Agents:

Synthetic binding agents are high molecular weight, long-chain organic polymers applied at much lower rates and promoted for their soil conditioning properties. These compounds effectively bind soil particles together, forming stable aggregates. Commonly used polymers include polysaccharides (PSD) and polyacrylamides (PAM), which help improve aggregate stability, preserve soil fertility, and prevent surface sealing. Applying small amounts (10–20 kg/ha), either directly to the soil or through irrigation water, has been found effective in stabilizing soil aggregates, especially in soils with high exchangeable sodium percentages (ESP > 20). These agents include anionic, catalytic, and non-viable polymers (Sojka et al., 2007).

b) Cationic Polymers:

Cationic polymers, such as polyvinyl chloride (PVC) and polyphenol hydrochloride (PPH), interact with clay particles through cation exchange, where calcium ions serve as a bridging agent between the clay and the polymer. These polymers are known for their strong flocculating ability, effectively causing clay particles to clump together (Evich et al., 2025)

c) Anionic Polymers:

Anionic polymers, including hydrolyzed polyacrylonitrile (HPAN) and vinyl acetate-maleic acid (VAMA) copolymers, are particularly useful in preventing surface crusting in highly sodic soils. These polymers form peripheral complexes that link clay particles in an edge-to-edge manner through hydrogen bonding. Although they lack flocculating power, they help stabilize already flocculated clays by adsorbing onto dispersed particles and creating bridges between them (Evich et al., 2025)

d) Non-Ionic Soil Conditioners:

Non-ionic conditioners like polyvinyl alcohol (PVA) interact with expanding clay minerals by forming intermicellar complexes, which help reduce swelling and enhance the stability of soil aggregates. This is achieved by coating the pores with polymer layers.

e) Polyacrylamide:

Polyacrylamide-based soil conditioners have been in use since the 1950s and were designed to enhance soil physical properties. They help reduce surface crusting, promote seedling emergence, and minimize runoff, erosion, and the loss of fertilizers and pesticides. As

synthetic binding agents, they are particularly effective in improving the structure of coarse-textured soils, which often suffer from poor physical quality due to a high proportion of macropores (Sartain, 1996).

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ARE WE PAINTING OUR HOMES HOT?

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Introduction

Global warming refers to the long-term rise in Earth's average temperature, largely due to the emission of greenhouse gases such as carbon dioxide (CO₂), methane (CH₄), and nitrous oxide (N₂O). These gases trap heat in the atmosphere, causing a warming effect that disrupts weather patterns and ecosystems. Since the late 19th century, global temperatures have risen by approximately 1.1°C, and this trend is set to continue unless greenhouse gas emissions are drastically reduced. As a result, climate change is leading to more extreme weather events, including more intense heatwaves.

Urban Heat Island (UHI) Effect

Urban areas experience significantly higher temperatures than rural regions due to a phenomenon called the **Urban Heat Island (UHI)** effect. This occurs because urban surfaces like asphalt, concrete, and buildings absorb and retain more heat than natural landscapes. The lack of vegetation, combined with human activities like transportation and the use of air conditioning, further amplifies the heat. The difference in temperature between urban and rural areas can be several degrees, leading to increased energy consumption, poor air quality, and heightened health risks, especially during hot summer months.

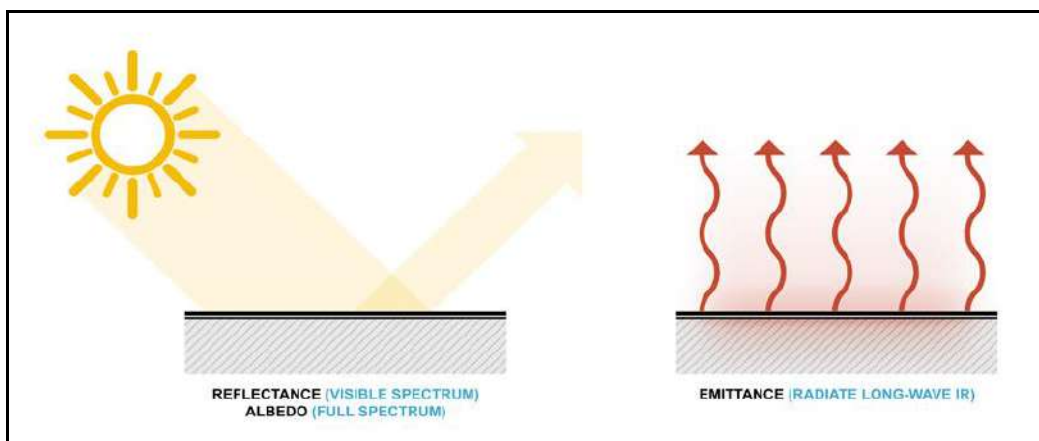
The UHI effect is directly tied to the **albedo** of urban surfaces. **Albedo** is a measure of a surface's reflectivity, representing how much sunlight is reflected back into the atmosphere versus how much is absorbed. Surfaces with high albedo, such as ice or light-coloured materials, reflect a significant portion of solar radiation, helping to cool the environment. In contrast,

surfaces with low albedo, such as dark-coloured roofs, roads, and buildings, absorb more heat, contributing to higher urban temperatures.



Paints, Solar Reflectance, and Cooling

To combat the UHI effect, one effective solution is the use of **cool materials**—specifically, paints and coatings with high solar reflectance (SR) and infrared (IR) emittance. These materials are designed to reflect more sunlight and release absorbed heat more efficiently. Currently, many commercially available “cool paints” and coatings are light-coloured or white, which maximize solar reflectivity and help lower the surface temperature of buildings. Until the previous generation, we have seen that houses were being painted using lime wash. The possible reason would be the high reflectance of white colour making the structures relatively cool. At present, we have made our houses hotter by painting them colourfully to satisfy our aesthetic pleasure. This shall be the right time to change back to traditional lifestyle of simple painting, while it is late than never.



For example, a simple experiment demonstrates how colours affect heat absorption: By focusing sunlight on white and black colour balloons simultaneously, we could visibly see that the black balloon bursting instantaneously, while the white colour balloon stays unharmed. The same effect can also be observed by leaving the two balloons outside on a bright sunny day. Interestingly, while a black balloon is left inside a white balloon and then focused with sunlight through a magnifying glass the black balloon inside the white one will burst, but the white balloon shall stay safe. This difference illustrates how dark and light colours react to solar radiation: light colours like white reflect more sunlight, staying cooler, while dark colours absorb more heat, causing a noticeable rise in temperature. A similar effect can be observed with urban materials. Dark-coloured surfaces like asphalt absorb up to 95% of the sun's rays, whereas white or light-coloured surfaces reflect up to 80%, significantly reducing heat absorption.

The Vicious Cycle of Heat in Urban Centres

Urban environments are particularly vulnerable to the UHI effect. As buildings absorb and re-radiate heat, the local temperature rises, leading to increased use of air conditioning, which in turn boosts energy consumption and carbon emissions. This creates a vicious cycle: more heat outside leads to greater demand for cooling inside, further straining energy resources and exacerbating global warming. In densely populated cities like those in India, China, Brazil, Indonesia, and Mexico, this cycle is especially pronounced, with record levels of energy consumption during the hot summer months. ★ ★ ★ ★

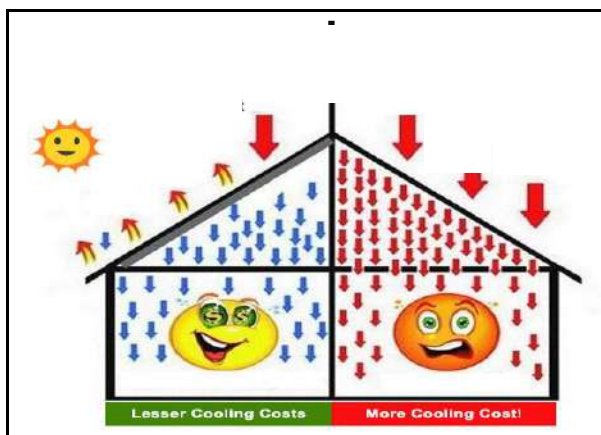
Benefits of Cool Roofs and Reflective Paints

Cool roofs and reflective paints offer a cost-effective way to mitigate the UHI effect. Studies show that white or light-coloured paints absorb less solar radiation and conduct less heat into buildings, reducing the demand for air conditioning. In fact, using cool materials can reduce cooling energy demand by up to 16% during the summer and lower overall energy consumption by about 3% annually. The building envelope, which includes the roof, walls, and windows, plays a critical role in maintaining thermal comfort. In hot climates, white or light colour paints have proven to perform better than some insulation materials, reducing heat absorption and enhancing comfort in non-air-conditioned buildings.



In India, where **HVAC (Heating, Ventilation, and Air Conditioning)** accounts for nearly 73% of energy use in buildings, the application of cool paints can drastically reduce energy consumption. Studies indicate that white or light colour applications can reduce cooling energy demand by as much as 54%, making it one of the most effective passive cooling strategies available. Unlike other technologies, white or light colour paints help maintain comfortable indoor temperatures without relying on external energy sources, making them an environmentally sustainable option.

Another interesting fact is that many NGOs in countries like Canada, United Kingdom, South Korea and Australia have taken up a mission called “Depavement” where patches of concrete/asphalt on roads and in cities are being removed and replaced with plants. This is to provide sufficient shade, increase green cover, encourage water drainage and biodiversity conservation. Greenways in India are also getting shape with this intention, thus we can redefine our Urban heat Islands into cool cities in the near future itself.



White or light colour paints Dark colour paints



Policy Support for Cool Paints and Urban Cooling

Given the significant impact of reflective paints and cool roofs in curbing the UHI effect and reducing energy consumption, governments should incentivize their use. Policies such as **tax reductions** or **subsidies** for individuals and businesses that choose energy-efficient paints (white or light colours) can encourage widespread adoption. Additionally, urban planning regulations could promote the use of high-reflectivity materials in construction to help mitigate the impacts of rising urban temperatures.

Conclusion

As urban populations continue to grow—an estimated 68% of the world's population will live in cities by 2050—the need to address the UHI effect is more urgent than ever. By increasing the use of white or light colour paints, cities **can reduce** temperatures, lower energy consumption, and contribute to global efforts to combat climate change. Choosing white or light-coloured paints is a simple yet highly effective step toward creating cooler, more sustainable urban environments. If the government and the people come together and are committed to this decision, we can ourselves paint our smart cities into cool cities.

IMPROVING NITROGEN USE EFFICIENCY THROUGH FERTILIZER MANAGEMENT IN UPLAND SOILS

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Abstract

Nitrogen is a crucial macronutrient and one of the most yield-limiting factors in crop production, especially under upland conditions. Despite its essential role in plant metabolism as a component of proteins, nucleic acids, and enzymes nitrogen use efficiency (NUE) in agriculture remains relatively low, with only 30-50% of applied nitrogen being utilized by crops. The rest is lost through various pathways such as volatilization, leaching, denitrification, and erosion, resulting in economic losses and environmental concerns. This document outlines strategies to improve NUE in upland agriculture, including soil, crop, and fertilizer management, site-specific nitrogen application, and the use of slow-release fertilizers and nitrification inhibitors. The adoption of diagnostic tools like chlorophyll meters and leaf colour charts, along with advancements in genetic engineering, further enhances the precision of nitrogen management. Additionally, optimizing the use of indigenous nitrogen sources such as crop residues, organic manures, and biological nitrogen fixation can significantly boost NUE. Collectively, these practices offer a sustainable approach to increasing crop productivity while minimizing environmental impact.

Key words: Nitrogen; Upland; Fertilizers; Management

Introduction

Nitrogen is one of the most yield-limiting nutrients in crop production, playing a critical role in plant growth and development. Plants absorb nitrogen primarily in the form of nitrate (NO_3^-) under aerobic conditions and ammonium (NH_4^+) under anaerobic conditions. As an

essential component of nucleic acids, proteins, and enzymes, nitrogen has a strong positive correlation with grain yield. However, nitrogen use efficiency remains a significant challenge in agriculture. According to Hierl *et al.*, only about 30–40% of the nitrogen applied through fertilizers is actually taken up by crops, with the remainder being lost to the environment through processes such as leaching, volatilization, and denitrification (Hierl, 1967).

Nitrogen Use Efficiency (NUE)

Nitrogen Use Efficiency (NUE) is the fraction of applied nitrogen removed from the field by the crop.

$$\text{NUE} = \frac{\text{Nitrogen removed from field in crop product (kg/ha)}}{\text{Fertilizer N applied (kg/ha)}} \times 100$$

Although the atmosphere contains approximately 78% nitrogen, this form is not directly available to most plants. In agricultural systems, nitrogen use efficiency (NUE) typically ranges between 30–50%, indicating that a significant portion of applied nitrogen is not utilized by crops. NUE serves as a practical and reliable indicator for assessing and monitoring the effectiveness and sustainability of fertilizer use. Leguminous crops generally exhibit higher nitrogen use efficiency compared to cereals, primarily due to their ability to fix atmospheric nitrogen through symbiotic relationships with *Rhizobium* bacteria (Yuan *et al.*, 2024). One of the main reasons for low NUE in many cropping systems is the loss of nitrogen from the soil in various forms such as leaching, volatilization, and denitrification—at different stages of the crop growth cycle.

Nitrogen loss

1. Ammonium volatilization
2. Nitrate leaching
3. Denitrification
4. Erosion/ Runoff

Ammonia Volatilization (21%):

This form of nitrogen loss occurs when nitrogen is released into the atmosphere as ammonia gas. It is particularly common when organic manures or urea-based chemical fertilizers are surface-applied (broadcasted) without incorporation into the soil. Warm temperatures, high soil pH, and lack of rainfall or irrigation after application can exacerbate volatilization.

Nitrate Leaching (20%):

Nitrate (NO_3^-), being highly soluble and not strongly retained by soil particles, is prone to leaching—especially in sandy soils with high permeability and under conditions of excessive rainfall or irrigation. This leads to the downward movement of nitrate beyond the root zone, making it unavailable to crops and posing environmental risks.

Denitrification (19%):

This is a microbial process where nitrate is reduced to gaseous forms such as nitrogen gas (N_2) and nitrous oxide (N_2O) under anaerobic (low oxygen) conditions. Soils with heavy texture and poor drainage are particularly susceptible to denitrification losses, especially when waterlogged conditions prevail.

Erosion and Runoff:

Nitrogen can also be lost through surface runoff and soil erosion. In humid and sub-humid areas, heavy rainfall can wash away nitrate nitrogen from the soil surface, while in arid and semi-arid regions, wind erosion can carry away nitrogen-rich topsoil. These processes significantly reduce the availability of nitrogen to crops and contribute to environmental degradation.

Approaches for Boosting Nitrogen Efficiency in Upland Agriculture

1. Soil management
2. Crop management
3. Fertilizer management
4. Site specific nitrogen management
5. Slow releases nitrogen fertilizer
6. Inhibitors (nitrification and urease)
7. INM

Soil management

Primary soil management plays a crucial role in enhancing nitrogen use efficiency (NUE), beginning with soil testing to assess the availability of essential nutrients, including nitrogen. Several soil factors influence nitrogen losses, such as pH, texture, structure, topography, and drainage. For instance, improving soil drainage helps prevent waterlogging, thereby reducing the risk of denitrification and leaching losses. Amendments like lime in acidic soils and gypsum in sodic soils can significantly improve soil conditions, thus enhancing NUE.

Additionally, the degradation of soil texture due to practices like puddling in rice cultivation can negatively impact nitrogen efficiency in subsequent wheat crops within rice-wheat cropping systems. Therefore, maintaining proper soil structure and balanced chemical properties is essential for sustainable nitrogen management in upland farming.

Crop management

Effective nitrogen use efficiency (NUE) can be enhanced through a combination of agronomic and genetic approaches. Sward management including factors such as plant age, species selection, nutrient balance, and regular soil and plant analysis plays a significant role in optimizing nitrogen uptake and utilization. Advances in plant breeding and biotechnology also contribute to improved NUE. The development of crop varieties with enhanced nitrogen assimilation capabilities offers a promising **avenue for** reducing the dependency on high nitrogen fertilizer inputs. Identifying and manipulating genes associated with efficient nitrogen use through genetic engineering can lead to crops that require less nitrogen while maintaining high yields. Notably, leguminous crops naturally exhibit higher NUE compared to cereals due to their ability to fix atmospheric nitrogen, making them valuable components in crop rotation systems aimed at improving overall nitrogen efficiency in agricultural landscapes.

Fertilizer management

The efficiency of nitrogen fertilizer use largely depends on appropriate management of the fertilizer source, application rate, and timing. To minimize losses and enhance uptake, nitrogen should not be applied before or during heavy rainfall events, which can lead to significant leaching and runoff. In wet conditions, such as paddy fields, ammonium-based ($\text{NH}_4^+\text{-N}$) fertilizers are preferred over nitrate-based ($\text{NO}_3^-\text{-N}$) fertilizers, as they are less prone to leaching and denitrification. Where soil application is impractical, such as in flooded rice fields, foliar application of nitrogen serves as an effective alternative (Wang et al., 2008). Additionally, deep placement of urea helps to reduce ammonia volatilization and ensures better nitrogen availability to plant roots. For crops grown under irrigated conditions, split application of nitrogen—applying smaller doses at different growth stages—enhances uptake efficiency and minimizes nutrient loss, leading to better crop performance and more sustainable fertilizer use.

Site Specific Nitrogen Management

Nitrogen management strategies can be tailored to improve efficiency based on crop needs and field conditions. Site-specific nitrogen management involves adjusting fertilizer

practices based on field-specific variability in crop nitrogen requirements and the soil's nitrogen supplying capacity. Real-time nitrogen management applies nitrogen only when leaf nitrogen content drops below a critical threshold, ensuring better synchrony between crop demand and nitrogen availability from soil or fertilizer. In contrast, fixed-time nitrogen management follows a predetermined schedule for nitrogen applications, where the timing and number of applications remain constant, but the rate is adjusted based on seasonal and locational factors.

Tools of SSNM

Tools like the chlorophyll meter and leaf colour chart are valuable for assessing nitrogen status in crops. A chlorophyll meter provides a relative measure of leaf chlorophyll content, which is directly proportional to the nitrogen content in the leaf, allowing for precise and timely nitrogen application. The leaf colour chart (LCC), on the other hand, is a simple, cost-effective diagnostic tool that helps farmers make informed decisions about nitrogen application in standing crops by visually comparing the greenness of leaves. Both tools support improved nitrogen use efficiency by aligning fertilizer application with the actual needs of the crop.

Slow release of fertilizer

Nitrate-containing fertilizers are highly susceptible to leaching because of the mobility of nitrate ions in the soil, while ammonium- and amide-based fertilizers are more prone to nitrogen loss through volatilization. Slow-release fertilizer (SRF) compounds can help reduce these nitrogen losses by delaying the release of nitrogen, thereby improving the synchronization between nitrogen availability and crop demand.

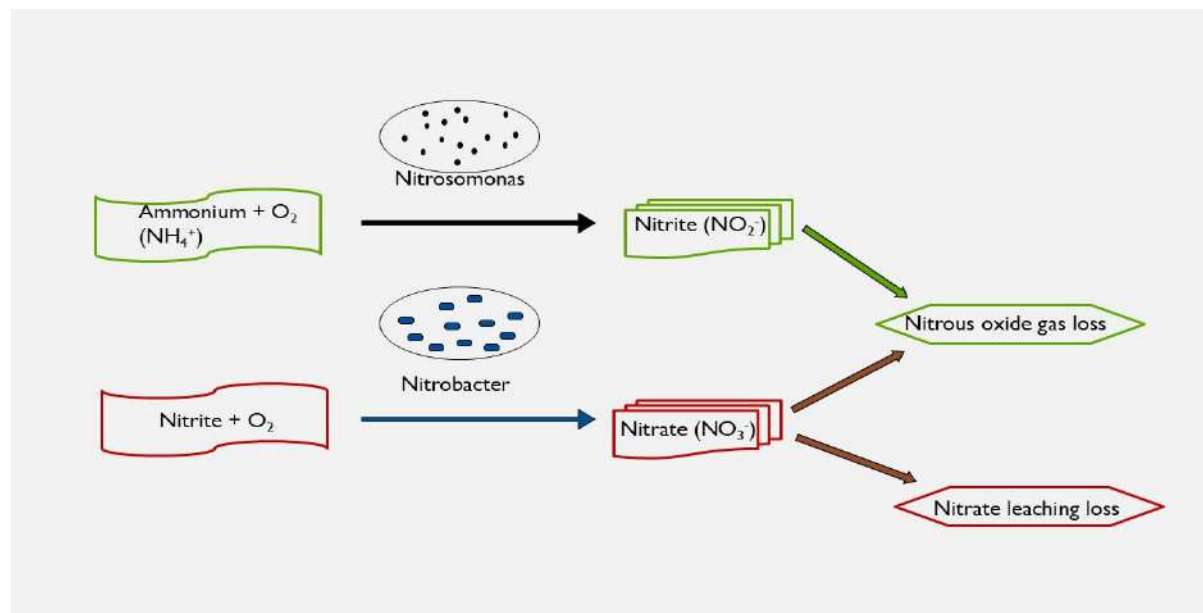
Nitrogen fertilizers with controlled-release properties can be classified into different types based on their mode of nitrogen release.

- (a) **Organic nitrogen low solubility compounds** include urea formaldehyde, which decomposes biologically, and iso butylidene diurea (IBDU), which decomposes chemically.
- (b) **Fertilizers with physical barriers** use coatings such as organic polymers, resins, or inorganic materials like sulfur to slow nitrogen release; examples include neem-coated urea, sulfur-coated urea, and urea super granules (USG).
- (c) **Inorganic low solubility compounds** like metal ammonium phosphate also provide a slow-release source of nitrogen due to their limited solubility in soil.

Nitrification inhibitors

These check bacterial oxidation of ammonium-N into nitrate-N and ensure high concentration of

ammoniacal form of nitrogen in soil ex: dicyandiamide, Nitrapyrin, Thiourea, calcium carbide.



Urease inhibitor

Inhibition of urea hydrolysis occurs by prevent or suppress over a certain period of time the transformation of amide-N in urea to ammonium hydroxide and ammonium through the hydrolytic action of the enzyme urease.

EX: N-(n-butyl) triphosphoric triamide (UAN), Thiosulfate, Hydroquinone

INM-Integrated nitrogen management

Optimizing the use of indigenous nitrogen (N) sources such as crop residues, organic manures, and biologically fixed nitrogen (BNF) from organisms like *Azolla* and blue-green algae alongside chemical nitrogen fertilizers can significantly enhance nitrogen use efficiency (NUE). These organic and biological sources contribute to a gradual and sustained release of nitrogen, improving soil fertility and microbial activity while reducing the risk of nitrogen losses through leaching or volatilization. When used in combination with chemical fertilizers, they create a synergistic effect, where the immediate availability of inorganic nitrogen complements the slow-release characteristics of organic forms. This integrated approach ensures a more consistent nitrogen supply throughout the crop growth cycle, promotes better root development, and supports sustainable soil health. Furthermore, the recycling of crop residues and use of biofertilizers like *Azolla* not only reduce dependency on synthetic inputs but also align with eco-

friendly and cost-effective farming practices, thereby contributing to long-term productivity and environmental sustainability.

Conclusion

Improving nitrogen use efficiency (NUE) is imperative for enhancing agricultural productivity and ensuring environmental sustainability, particularly in upland farming systems. A significant portion of applied nitrogen is lost through volatilization, leaching, and denitrification, underscoring the need for precise and integrated management practices. Effective strategies encompass tailored fertilizer application based on crop needs and soil characteristics, the use of slow-release formulations and inhibitors, and the incorporation of site-specific and real-time decision-making tools. Additionally, integrating organic sources and leveraging biological nitrogen fixation contribute to a **more balanced** and sustainable nitrogen economy. Advancements in plant breeding and biotechnology further open avenues for developing crop varieties with enhanced nitrogen uptake and assimilation. Together, these multidisciplinary approaches provide a foundation for maximizing nitrogen efficiency while reducing environmental impact and ensuring long-term food security.

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BANANA: A HEALTHY FRUIT ROUND THE YEAR

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Introduction

India with its rich agricultural heritage and being one of the largest fruit producing countries globally. The banana plant holds a reserved place in our Indian culture. Banana is grown by farmers in lakhs of hectares of land and it is the mainstay of farmers with small agricultural land. The banana is known to have evolved in the humid tropical regions of South-eastern Asia. Today, bananas are grown on almost all continents in tropical and subtropical climates with temperatures between 15°C – 35°C and high humidity, thriving on well-drained red loam or black soil. Bananas accounted for 31.50% of the total fruit production, while mangoes accounted for 19.8%. India is the largest producer of bananas in the world, accounting for 26.56%. India produces an estimated 94.2 million tonnes of banana (FAO, 2021).

Banana is a sweet yellow fruit, that is readily available throughout the year. It is not just the fruit with taste, also it has innumerable benefits. Bananas are rich in potassium, fiber, magnesium, folate and other essential nutrients. This is why it improves blood sugar levels, improves digestion to support heart health, bathes for weight loss, good for the kidneys and aids in recovery.

In India

Out of the 28 states of India, 26 states grow bananas. 23% of banana supplied by Tamil Nadu to

India. Maharashtra and Gujarat has second and third largest respectively. Andhra Pradesh, Karnataka, Bihar, Madhya Pradesh, Uttar Pradesh, West Bengal and Assam are other major banana growing states. Rajasthan, a low-yielding state, grows only one ton of the fruit per year.

India's fertile soil supports hundreds of banana varieties, but farmers commercially cultivate only about 12 individual varieties. Each of these varieties varies subtly in their taste, appearance and aroma According to the book "Fruit Crops" India mostly exports the dwarf Cavendish and Robusta varieties and the locals consume the Poovan, Rasali, Virupakshi varieties.

India's fruit production is estimated at 112.62 million metric tonnes in 2023-24. It expects production to be 110.21 million metric tonnes in 2022-23, an increase from then.

Varieties of Banana

Robusta

Robusta is a widely known variety of bananas in India. It is semi-tall and grown mostly in Tamil Nadu, Andhra Pradesh, Maharashtra and some parts of Karnataka for table purpose.



Some of the key characteristic features are:

It is a high yielding variety with dark green in colour that turn bright yellow upon ripening.

It produces bunch of large size weighs around 25-30 kg and has a sweet aroma.

It is often used in cooking and is a popular ingredient in South Indian cuisine.

However, storage and transportation of these bananas is a challenge. Also, these banana variety are susceptible to Sigatoka leaf spot disease which is very destructive disease of bananas.

Dwarf Cavendish

Dwarf Cavendish is one of the most cultivated variety of bananas in India. It is widely famous and are grown extensively for table and processing purpose in the states Maharashtra, Gujarat, Bihar and West Bengal.

'Basrai' is the leading commercial variety of Cavendish group of bananas cultivated in Maharashtra. It is also popular in Andhra Pradesh, Karnataka and Tamil Nadu.



The key features are:

It is dwarf in stature that is why it is less prone to wind damage.

It's bunch weighs around 15-25 kg.

This variety also performs well under light soils.

It is green in colour which remains the same even after ripening.

In India, these types of bananas are often used in desserts like banana bread, banana pudding and banana chips.

Rasthali

Rasthali, also known as silk variety of bananas is widely popular and grown in the southern states like Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Bihar.

Some of the key features are:

It is a mid-tall variety of bananas and is a highly priced cultivator for table purpose.

Throughout its development, it has yellowish green colour, but turns pale to golden yellow after ripening.

It has thin skin and easy to peel and the texture resembles to silk that is why it is also known as silk banana.

These bananas usually are eaten as a snack when fully ripe or used in cooking, particularly in South Indian cuisine.

However, the production of this banana variety is expensive due to factors like longer crop duration, susceptibility to Furasium wilt, and formation of hard lumps.



Poovan

Poovan is also known as Champa or Mysore. It is one of the major commercially cultivated throughout the country. It is widely grown in KarpuraChkkarakeli in Andhra Pradesh, Alpan in the North East Region, Poovan in Tamil Nadu, and Palayankodan in Kerala. Due to its climatic and marginal soil condition, Tamil Nadu is the major producer of poovan cultivar.



Some of the key characteristics are:

The fruit is slightly acidic and firm and has attractive golden yellow colour.

It is known for its sour-sweet taste and aroma.

It is medium sized variety with good keeping quality.

It is resistant to fruit cracking which makes this variety different from others.

These bananas are generally cultivated as a perennial crop. In Tamil Nadu and certain regions of Kerala, it is cultivated commercially for leaf industry.

Nendran

Nendran is a popular variety of bananas in Kerala. It is not only used as a fruit but also in processing. This variety is popular for its diversified stature. They are often used for making traditional dishes and tasty snacks.

Some of the key features are

It has pseudo stem colour in the early stages of its growth.

The bunch has 5-6 hands which weighs around 12-15 kg.

These bananas are green in colour which turns buff yellow when ripened.

It remains starchy even after ripening.



Red Banana

Red bananas are widely popular in the states like Kerala and Tamil Nadu. It is highly priced variety in these states. Its commercial cultivation is prominent in Tirunelveli and Kanyakumari districts of Tamil Nadu. It is popular as LalVelchi in Bihar and other regions and as Chandra Bale in Karnataka.



Some of the key features are

Red bananas have reddish-purple skin and a sweet, creamy flesh.

They are smaller than cavendish bananas and has delicious & sweet taste.

It has creamy texture and nice aroma.

Its bunches weigh around 20-30 kg.

These bananas have fruity undertones similar to raspberries and mangoes when fully ripened.

Many other varieties of banana are Ney Poovan, Virupakshi, Vanchanandan, Mondhan, Karpande, Cardamom, Rajavuri G-9, Madhuranga, Pachabale etc.

In recent years India has developed new varieties of bananas such as KaveriSaba, KaveriKalpi , KaveriHarita, KaveriKanya, KaveriSugandham, Udayam etc.

Uses

The banana leaves, banana flower, banana nut, banana fruit, its stem, banana stem, etc., every part of the banana is useful for humans.

Trunk

The trunk of the banana tree is used for construction purposes such as temporary shelters, building fences or even as a source of wood pulp.

Leaves

The large, flexible leaves of the banana tree have multiple uses. In many cultures they are used as natural food wrappers, eco-friendly bundles and serving utensils. The leaves also act as shade, protecting crops and gardens from excessive sunlight.

Banana flower

Banana flowers are not only aesthetically pleasing, but also have culinary applications as they are used in various traditional dishes, salads and curries. Adds a unique flavor and texture to the dish.

Fruit

Undoubtedly the most famous part is the banana, which is consumed all over the world. From being enjoyed fresh to being added to smoothies, sweets or savory dishes, bananas are versatile.

Banana peel

We all tend to throw away the thick yellow peels after eating a banana, but should know that the peels of this fruit are actually rich in nutrients and provide numerous health benefits. The peels of this fruit help in digestion. Increases the production of white blood cells and strengthens the immune system. The fibrous peels of this fruit provide several health benefits, as well as enhance the glow of the face.

Raw banana

Most people like to eat ripe bananas. But green unripe bananas are neglected as these green unripe bananas have lower sugar content compared to ripe bananas and are a good source of fiber

and calcium. Consuming these bananas helps regulate bowel movements, improves digestion and is also beneficial for diabetic patients.

Banana juice

Drinking lemon juice adding with banana juice plays a very important role in dissolving kidney stones and preventing urinary tract infection. Helps to control the acidity of the stomach Heartburn, rumbling in the stomach, burning sensation in the stomach, Banana is a panacea for all these. Bananas are helpful in preventing diabetes because vitamin B6 deficiency affects the body in diseases like diabetes.

Benefits

Nutritional Powerhouse:

Bananas are packed with essential nutrients including potassium, vitamin C and dietary fiber. Including bananas in your diet can help maintain heart health, control blood pressure and improve digestion.

Sustainable material :

Banana tree leaves and stems are excellent sources of sustainable materials. These materials can be used to make household items such as baskets, mats and furniture.

Organic Manure :

Banana peels are rich in nutrients like potassium, phosphorus and calcium. They can be composted to make organic manure, promoting healthy soil and plant growth.

Summary

Establishing appropriate eating habits is essential for maintaining good health. By adopting these simple tips into your daily routine, you can guarantee that you are nourishing your body with nutrient-dense foods that supply you with the energy and nutrition you need to thrive. Bananas are a popular fruit that contain essential nutrients that help to keep a person healthy. Nutrients in bananas can promote health and prevent disease, benefiting everything from the feet of the banana to the skin.

.. BANANA NUTRITION ..



BANANA (100g)
ENERGY - 89 kcal
PROTEIN - 1.1 g
CARBOHYDRATES - 23 g
TOTAL FAT - 0.3 g
FIBER - 2.6 g
SUGARS - 12 g
CHOLESTEROL - 0 mg
SODIUM - 1 mg
POTASSIUM - 358 mg
MAGNESIUM - 27 mg
PHOSPHORUS - 22 mg
CALCIUM - 5 mg
IRON - 0.26 mg
ZINC - 0.15 mg



DRIED VEGETABLES: A GAME CHANGER IN THE HORTICULTURE INDUSTRY, REDUCING WASTAGE, AND IMPROVING ECONOMIC OUTCOMES

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Abstract

The horticulture industry faces significant challenges related to post-harvest losses and economic viability. This study examines the potential of dried vegetables as a game changer in addressing the current challenges. We explored the impact of vegetable drying technologies on reducing wastage, enhancing shelf life, stabilizing prices, and improving economic opportunities for farmers and related stakeholders and also the economic benefits of dried vegetables, considering factors like transportation costs, storage requirements, and market accessibility. Furthermore, it identifies challenges and opportunities associated with the adoption and scaling up of vegetable drying initiatives. The study suggests that dried vegetables offer a viable pathway towards a more sustainable and economically resilient horticulture sector, particularly in regions with high post-harvest losses and limited access to efficient cold chain infrastructure.

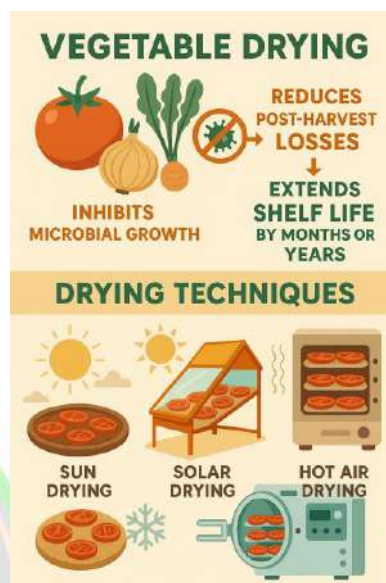
Keywords: Dried Vegetables, Horticulture, Post-Harvest Losses, Economic Impact, Food Security, Sustainability, Value Addition

Introduction

The horticulture industry plays a vital role in global food security, nutrition, and economic development. However, a significant portion of horticultural produce, especially vegetables, is lost post-harvest due to factors such as inadequate infrastructure, improper handling, lack of processing facilities, and market inefficiencies (FAO, 2011). These post-harvest losses (PHL) not only contribute to food insecurity and economic hardship for farmers

but also represent a waste of valuable resources, including water, land, and energy used in production (Kummu et al., 2012). The magnitude of vegetable PHL varies across regions, with developing countries often experiencing higher rates due to limited access to advanced preservation technologies and efficient supply chain management (Affognon et al., 2015).

Given the significant challenges posed by PHL, innovative strategies are needed to transform the horticulture industry into a more sustainable and economically viable sector. Dried vegetables have emerged as a promising solution for mitigating wastage and enhancing the value of horticultural produce. Drying, one of the oldest methods of food preservation reduces the water activity of vegetables, thereby inhibiting microbial growth and enzymatic degradation, extending shelf life, and simplifying storage and transportation (Fellows, 2017). Dried vegetables can also be incorporated into a variety of food products, offering convenience and nutritional benefits to consumers.



1) Impact on Reducing Post-Harvest Losses

Across numerous studies, the effectiveness of drying significantly reducing post-harvest losses in vegetables was consistently demonstrated. Drying inhibits microbial growth and enzymatic activity, thereby extending the shelf life of vegetables from a few days to several months, and even years in some cases (e.g., Bediang et al., 2011; Doymaz, 2005). This is particularly crucial for perishable vegetables like tomatoes, leafy greens, and onions, which are prone to rapid spoilage. Studies have shown that drying can reduce post-harvest losses in these vegetables by 50%-80% compared to fresh produce (e.g., Gupta et al., 2002).

Different drying techniques, including sun drying, solar drying, hot air drying, and freeze-drying, have varying impacts on product quality and preservation effectiveness. While sun drying is a simple and cost-effective method, it is susceptible to contamination and insect infestation, leading to lower product quality and potentially higher losses (Ekechukwu, 1999). Solar dryers offer improved control and hygiene compared to sun drying, resulting in better product quality and reduced losses (e.g., Bala, 2017). Hot air drying provides faster drying rates but can lead to nutrient degradation and shrinkage if not properly controlled (Mujumdar, 2007).

Freeze-drying, although the most expensive method, offers the best product quality in terms of nutrient retention, color, and texture (Ratti, 2001).

2) Economic Benefits for Farmers and Stakeholders

The application of vegetable drying technologies offers substantial economic benefits for farmers and other stakeholders involved in the horticulture value chain. Dried vegetables can be stored for extended periods, allowing farmers to sell their produce when prices are more favorable, mitigating the impact of seasonal price fluctuations (e.g., Adebayo et al., 2010). This price stabilization can significantly increase farmer income and reduce vulnerability to market volatility.

Furthermore, dried vegetables are lighter and less bulky than fresh produce, which reduces transportation costs and expands market reach. Dried products can be transported to remote areas with limited access to cold chain infrastructure, opening up new market opportunities for farmers (e.g., FAO, 2012). The reduced transportation costs also make dried vegetables more competitive in both domestic and international markets.

The processing of vegetables into dried products creates employment opportunities in rural areas, particularly for women (e.g., UNIDO, 2011). Small-scale drying enterprises can provide a source of income for rural communities and contribute to local economic development. The value-added processing of vegetables also increases the overall profitability of the horticulture industry.

3) Sustainability Considerations

The environmental impact of vegetable drying depends on the type of drying technology used and the energy source employed. Sun drying, while cost-effective, can contribute to air pollution due to dust and contamination. Solar drying offers a more environmentally friendly alternative, utilizing renewable energy to reduce greenhouse gas emissions (e.g., Okoroigwe et al., 2018). However, the efficiency of solar dryers can vary depending on weather conditions and design.

Hot air drying can be energy-intensive if powered by fossil fuels. The environmental impact of hot air drying can be reduced



by using renewable energy sources, such as biomass or solar thermal energy (e.g., Togrul & Togrul, 2003). Freeze-drying, while producing high-quality products, is the most energy-intensive drying method and has the highest environmental footprint.

The reduced post-harvest losses associated with vegetable drying contribute to a more sustainable food system by minimizing the waste of resources used in production, such as water, land, and energy (e.g., Kummu et al., 2012). By extending shelf life and reducing transportation costs, dried vegetables can also reduce the environmental impact of food distribution.

4) Challenges and Opportunities

Despite the numerous benefits of dried vegetables, several challenges hinder their wider adoption and scaling up. Consumer acceptance of dried vegetable products can be a major barrier, particularly in regions where fresh produce is preferred (e.g., JICA, 2008). Addressing this challenge requires consumer education and awareness campaigns to highlight the nutritional benefits, convenience, and affordability of dried vegetables.

Maintaining product quality during drying and storage is also crucial for consumer acceptance. Proper drying techniques and packaging materials are needed to prevent nutrient degradation, color changes, and microbial contamination (e.g., Sacchetti et al., 2005). Quality control measures, such as regular testing and certification, are essential for ensuring the safety and integrity of dried vegetable products.

Access to appropriate drying technology and financing is often a constraint for small-scale farmers and processors. Affordable and efficient drying equipment is needed to enable widespread adoption of vegetable drying initiatives. Government support, including subsidies, training programs, and access to credit, can play a vital role in promoting the use of drying technologies.

Conclusion

Dried vegetables offer a viable and promising solution for mitigating post-harvest losses and improving economic outcomes in the horticulture industry. By extending shelf life, reducing transportation costs, and stabilizing prices, dried vegetables can significantly enhance the sustainability and resilience of the food system. However, the broader adoption of vegetable drying technologies requires addressing challenges related to consumer acceptance, product quality, and access to appropriate technology. Further research is needed to optimize drying

processes, develop innovative dried vegetable products, and assess the long-term economic and environmental impacts of vegetable drying initiatives.

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SMART AND SCIENTIFIC TECHNOLOGICAL INNOVATIONS FOR MODERN BLUE GROWTH

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Abstract

The world of aquaculture is changing fast and for the better. With growing global demand for seafood, we need smarter, more sustainable ways to farm fish and other aquatic species. That's where the latest scientific and technological innovations are stepping in to transform the fisheries and aquaculture sector. From smart tools like IoT (Internet of Things) sensors and AI-powered monitoring systems to automated feeding machines, today's farms are becoming more efficient, precise, and eco-friendly. These technologies help farmers make better decisions based on real-time data, reducing waste and improving productivity. On the scientific front, powerful tools such as CRISPR-Cas9 for genome editing, marker-assisted selection (MAS), and newly developed vaccines are opening up new possibilities in fish breeding and disease prevention. Meanwhile, advanced systems like Recirculating Aquaculture Systems (RAS), Integrated Multi-Trophic Aquaculture (IMTA), and Biofloc Technology are helping us farm more with less using less space, less water, and causing less harm to the environment.

This article offers a glimpse into how these innovations are reshaping aquaculture making it smarter, cleaner, and more climate-resilient. If you are student, a farmer, a researcher, or just someone curious about the future of food, these breakthroughs are paving the way for a more responsible and intelligent Blue Economy.

Key words

- Marker Assisted Selection (MAS)
- Blue growth
- IMTA

- Artificial Intelligence
- sea ranching
- Bio technology
- Bioremediation
- Aquaponics

Introduction

Aquaculture is the booming sector and in food industry around the globe and Contributing around 50% of food, and 20% of animal protein (1). In upcoming decades the population will increase and there will not be sufficient food. So to ensure the global food and nutrition security to the coming generations it is essential to adopt new smart and scientific technologies. It is important to reduce the environmental impacts from aquaculture while adopting these technologies. In this article we explores about how these new innovative technologies used in aquaculture, will changed the scenario of aquaculture production and livelihood of fish farmers.

Need for scientific & smart technologies

These emerging innovations are significantly contributing to global food security, employment generation, and the economic growth of the aquaculture sector. By increasing efficiency and productivity, they help meet the rising demands of a growing global population while reducing the pressure on wild fish stocks and mitigating the problem of overfishing. Importantly, these technologies also aim to address the environmental challenges traditionally associated with aquaculture. Through smarter and more sustainable practices, they minimize ecological footprints, promote resource efficiency, and support the long-term health of aquatic ecosystems.

Scientific Innovative technologies in aquaculture

Selective breeding

Innovative breeding technologies in aquaculture have enabled improved characterization of hybrids with desirable traits such as faster growth rates, enhanced disease resistance, and greater tolerance to environmental stress (2). Parent fish are typically selected based on favorable phenotypic traits, and when bred, they can produce offspring (hybrids) that express these improved characteristics. However, it is important to note that the expression of such traits depends not only on visible features but also on the genetic makeup of the parent stock. If the

desirable traits are not strongly inherited at the genotypic level, they may not consistently appear in the next generation. Additionally, producing stable and high-performing hybrids often requires time and careful selection across multiple breeding cycles to ensure the desired traits are reliably passed on

Biotechnological tools

The application and deeper understanding of gene regulation and expression in aquaculture are made possible through biotechnological research (3). These advancements have paved the way for significant breakthroughs such as the development of transgenic fish and the advanced cryopreservation of gametes, both of which hold great potential for improving breeding efficiency, genetic conservation, and production outcomes in aquaculture.

Bioremediation techniques

Biotechnology also benefits farmers by enabling the degradation of hazardous wastes into environmentally safe by-products. This process is facilitated by the activity of specific aquatic organisms and beneficial microbes, which play a crucial role in maintaining water quality and ecosystem balance (4). Such bioremediation approaches contribute to more sustainable and eco-friendly aquaculture practices.

sea-ranching in aquaculture

In this approach, juvenile fishes are produced in hatcheries and subsequently released into the sea, where they grow under natural conditions. When implemented with proper regulatory frameworks and effective management strategies, this technology significantly contributes to enhancing overall fish landings along coastal regions (5). It plays an important role in stock enhancement, supporting both biodiversity conservation and fisheries productivity.

Eco friendly feed formulation

Eco-friendly feed formulations in aquaculture are increasingly being developed using alternative protein sources such as insect-based meals and plant-derived ingredients. Unlike traditional animal protein sources which are often rich in phosphorus and contribute to phosphorus pollution in aquatic environments these alternatives offer a more sustainable solution (6). In addition to reducing nutrient pollution, the use of alternative proteins also helps alleviate the growing pressure on fishmeal resources, supporting more responsible and environmentally sound aquaculture practices.

Recirculatory aquaculture system(RAS)

Recirculating Aquaculture System (RAS) is a recently developed technology where water is continuously recirculated and reused after undergoing mechanical and biological filtration to remove suspended solids and metabolic wastes. As a closed-loop system, RAS significantly reduces water consumption and minimizes environmental impact by preventing discharge of untreated effluents. This system allows for precise control over critical water quality parameters such as temperature, oxygen, and ammonia levels, creating optimal conditions for fish health and growth. Additionally, RAS is especially beneficial for fish farming in landlocked or urban areas, where access to natural water bodies is limited, and it helps reduce the risk of disease outbreaks by maintaining a controlled environment.

Biofloc technology

This system primarily functions by recycling nutrients derived from uneaten feed and fish excreta. Specially selected microbes are introduced into the water to convert these leftover organic wastes and toxic substances into valuable microbial protein.(7) This natural recycling process not only helps in maintaining water quality but also supports higher stocking densities, ultimately leading to increased production yields within the system.

Triploidy Induction

This technology is employed to produce completely sterile individuals, which helps overcome challenges such as hermaphroditism in fish species. By ensuring sterility, it prevents unwanted reproduction and contributes to better management of breeding and stock quality in aquaculture operations.

Aquaponics

Integrated aquaculture combines fish farming with hydroponic plant cultivation, creating a synergistic system that generates two sources of income for farmers.(8) This approach not only maximizes resource use efficiency by recycling nutrients from fish waste to nourish plants but also enhances overall farm productivity and sustainability.

Innovations from ICAR Institutions**Technologies by ICAR-Central Institute of Fisheries Education (CIFE).**

Established in 1961, the Central Institute of Fisheries Education (CIFE) is a premier national institute and university dedicated to the advancement of the fisheries sector. It offers postgraduate and doctoral programs aimed at training fisheries professionals and

researchers. CIFE has developed a range of innovative technologies that have significantly contributed to aquaculture and fisheries, including vaccines like CIFE-FLAVAC (against columnaris disease), CIFE-EDVAC (targeting *Edwardsiella*), and CIFE-ADVAC (for *Aeromonas* infection). Other notable innovations include MAHAMAGUR (a fish feed), CIFE ARGUNIL, water quality test kits, solar-powered fish coolers for fresh fish storage, floating carp hatcheries for reservoirs, Fish ANUre™ (organic manure derived from fish waste), automatic fish feeders, and efficient fish drying racks. (10) These technologies support sustainable fisheries development and help improve productivity, fish health, and post-harvest management, benefiting farmers and the entire aquaculture industry.

Technologies by ICAR-Central Institute of Fresh Water Aquaculture (CIFA)

The Central Institute of Freshwater Aquaculture (CIFA) has developed several important technologies to advance freshwater aquaculture. These include the Jayanti Rohu strain, developed through selective breeding for improved growth and performance, as well as FRP portable hatcheries that facilitate flexible and efficient seed production.

CIFA has also produced specialized feeds tailored to the different life stages of fish, enhancing nutrition and survival rates. Additionally, the institute has developed disease detection kits such as CIFA Cure for identifying bacterial and fungal infections in ornamental fish, along with CIFA-CRYO, which supports advanced cryopreservation techniques. These innovations contribute significantly to the productivity, health management, and sustainability of freshwater aquaculture systems.

Technologies developed by National Fisheries Development Board (NFDB).

Established in 2006, the National Fisheries Development Board (NFDB) plays a pivotal role in promoting aquaculture and fish production across India. The board supports the adoption of innovative technologies aimed at enhancing fisheries productivity and sustainability nationwide. (9) Some of NFDB's key initiatives include the development of wetland fisheries in coastal states, the establishment of Aqua One Centres (AOC) that provide technical services to fish farmers, and the promotion of cage culture in inland open waters using Indian Major Carps (IMC). In collaboration with ICAR-CMFRI, NFDB also supports brackish water cage culture in states like Kerala and West Bengal, focusing on species such as milkfish, sea bass, and mullet. Other advancements include the culture of silver pompano in brackish water ponds, sea cage farming, seaweed cultivation, backyard recirculatory aquaculture systems (RAS), and integrated

farming models such as paddy-cum-fish culture. These innovations collectively contribute to sustainable growth and diversification of India's aquaculture sector.

sea weeds for valuable nutraceuticals

Seaweeds are large, macro algal plants found predominantly along coastal shelf areas. In India, the most common and commercially important groups of seaweeds include green algae (Chlorophyta), brown algae (Phaeophyta), and red algae (Rhodophyta). Notable species such as *Gracilaria edulis*, *Gelidiella acerosa*, *Kappaphycus alvarezii*, and *Sargassum* play a significant role in the country's seaweed industry. These seaweeds are rich sources of nutraceutical compounds, and research on their extraction and applications is actively conducted by institutes like ICAR-CMFRI and ICAR-CIFT. Some innovative nutraceutical products developed by CMFRI include Cadalmin[®]GAE (anti-arthritic agent), Cadalmin[®]IBe (immunity booster), Cadalmin[®]MBC (probiotic), as well as CIFTEQ[®] seaweed-based products such as seaweed cookies, hand sanitizers, and Aqua Booster fish feed. Such advancements highlight the growing importance of seaweeds not only as nutritional supplements but also as sustainable resources for health and aquaculture industries.

Some of the commercialized scientific technologies in fisheries

- Development of fish species and breeds such as Bhakti and Shining Barb, as well as ornamental fish varieties.
- Portable FRP carp hatcheries that facilitate efficient seed production.
- Specialized CIBA-formulated shrimp feeds designed to optimize growth and health.
- Fish Aggregating Devices (FADs) that aid in enhancing fish catch in coastal waters.
- Cadalmin[™] Gme, a product derived from marine resources with health and aquaculture applications.
- Chitin and Chitosan, biopolymers extracted from crustacean shells, widely used for their antimicrobial and bio stimulant properties.
- Micro-analysis kits for detecting critical water quality parameters such as ammonia, nitrite, and phosphorus, essential for maintaining optimal aquaculture system health.
- Immunoboost-C, a health supplement to enhance fish immunity.
- Fish Munch and Fish Kure, products developed for improving fish nutrition and disease management.

Smart and precision innovation technologies in aquaculture

Artificial Intelligence (AI) is one of the most promising smart technologies being applied in aquaculture today (Fearn, 2018). AI enables machines to perform intelligent tasks, offering great potential to enhance precision and efficiency in aquaculture operations. The Internet of Things (IoT) complements AI by automating equipment such as pumps, aerators, and motors, which can be remotely controlled based on real-time sensor data. This automation greatly benefits farmers by optimizing resource use and reducing manual intervention. Innovations like underwater drones are increasingly used to monitor water quality parameters such as dissolved oxygen, and detect chemical and physical changes in ponds. These drones also assist in identifying and repairing damaged nets. A recent commercial innovation in this field is the AI-powered underwater drone, Eye Rov Tuna, which exemplifies the integration of AI and robotics in advancing sustainable and precision aquaculture.

AI in aquaculture

One of the key strengths of Artificial Intelligence (AI) in aquaculture lies in its ability to process and analyze vast amounts of data, enabling data-driven decision-making that optimizes the entire production process (11). By utilizing sensors and cameras, AI systems continuously collect and interpret real-time information to improve operational efficiency (12). These technologies facilitate precise monitoring of underwater fish movement, feeding behaviors, and overall fish health, allowing farmers to respond proactively to any changes or issues within the system. As a result, AI-driven aquaculture contributes to increased productivity, resource optimization, and sustainable farming practices.

AI in Disease management

Artificial Intelligence plays a central role in the early detection of diseases in aquaculture. By employing advanced AI algorithms, these technologies can identify abnormal fish behaviour such as erratic swimming, lethargy, and other unusual movements before diseases become widespread. This early intervention capability helps farmers take timely action, reducing losses and improving overall fish health management. AI plays a Central role in disease detection, before it get wide spread the technologies like AI algorithms are helps in the detection of the abnormal behavior like abnormal swimming, lethargy, erratic swimming etc. of the fish (13).

AI in feed efficiency optimization of fish

Artificial Intelligence also plays a crucial role in monitoring and analysing feeding behaviour in aquaculture (14). By evaluating growth rates, feeding patterns, and nutritional needs, AI systems optimize feed efficiency, ensuring that fish receive the precise amount of feed required at the right times. This tailored feeding schedule not only reduces feed wastage but also minimizes water contamination caused by excess feed, contributing to a healthier and more sustainable aquaculture environment (15).

e-fishery smart sensor feeder

Equipped with advanced sensors, modern feeding systems can detect the hunger levels of shrimp and fish, enabling the precise release of feed from the feeding trays. This technology helps optimize feed distribution and has been shown to reduce feed costs by approximately 21%.

Conclusion

The integration of smart and scientific technologies is revolutionizing the aquaculture sector, driving it toward greater precision, sustainability, and productivity. Innovations such as Artificial Intelligence, Internet of Things (IoT), advanced breeding techniques, eco-friendly feed formulations, and recirculatory systems are enabling farmers to optimize resource use, improve fish health, and minimize environmental impacts. AI, in particular, plays a transformative role by facilitating real-time monitoring, early disease detection, and efficient feeding practices that reduce waste and enhance overall system performance. Coupled with cutting-edge biotechnological advancements and sustainable management approaches, these technologies are shaping the future of aquaculture, ensuring it can meet the growing global demand for seafood while safeguarding ecosystem health. As these innovations continue to evolve and become more accessible, they offer immense promise for empowering farmers, researchers, and stakeholders to build a more intelligent and responsible blue economy.

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SOIL MICROBIOME DYNAMICS AND THEIR ROLE IN SUPPRESSING SOIL-BORNE PLANT PATHOGENS: MECHANISMS, MANAGEMENT, AND FUTURE PROSPECTS

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Abstract

Soil-borne plant pathogens represent a major constraint in agricultural productivity, threatening food security globally. However, natural disease suppression through soil microbial communities offers a promising alternative to conventional chemical controls. This review explores the dynamic interactions between soil microbiomes and plant pathogens, emphasizing the role of beneficial microbes in disease suppression. The mechanisms underlying microbial antagonism, such as competition, antibiosis, and induced systemic resistance, are discussed in detail. Furthermore, the influence of soil health indicators, amendments, and climatic factors on pathogen proliferation is examined. Advances in biocontrol strategies and molecular diagnostics are also reviewed, along with the emerging role of soil microbiome engineering. Challenges such as microbial variability, environmental fluctuations, and the need for predictive tools are identified. The review concludes by highlighting future research directions in enhancing sustainable disease management through microbiome-based soil interventions.

1. Introduction to Soil-Pathogen Interactions

Soil is not merely a physical substrate for plant anchorage; it is a dynamic ecosystem teeming with diverse microbial communities that play essential roles in nutrient cycling, organic matter decomposition, and plant health. Among the complex interactions occurring in the rhizosphere, the interplay between soil microbes and plant pathogens has profound implications for agricultural sustainability. Soil-borne pathogens such as *Fusarium*, *Rhizoctonia*, *Pythium*, and *Phytophthora* are responsible for significant yield losses in a wide array of crops. Unlike foliar

diseases, these pathogens are particularly difficult to manage due to their persistence in the soil and often asymptomatic infection stages. However, soil microbiomes—comprising bacteria, fungi, archaea, and protozoa—can naturally suppress these pathogens through a variety of mechanisms. Understanding the dynamics of these interactions offers a pathway to designing sustainable soil-based disease management strategies.

In recent years, advances in microbial ecology have revealed the vast complexity and functional diversity of the soil microbiome. The rhizosphere, in particular, represents a hotspot for microbe-plant interactions, often referred to as the "second genome" of the plant. Root exudates serve as chemical signals and nutrient sources that shape microbial community composition, influencing both beneficial and pathogenic organisms. Plants and microbes co-evolve in this environment, resulting in intricate signaling networks that can determine disease outcomes. Moreover, the soil microbiome acts as a buffer against pathogen invasion by occupying ecological niches and modulating environmental conditions unfavorable to pathogens. A deeper exploration of these interactions is critical, especially in the context of sustainable agriculture and climate change resilience.

2. Overview of Soil-Borne Plant Pathogens

Soil-borne plant pathogens are typically fungi, oomycetes, nematodes, or bacteria that infect plants through the root system, causing diseases such as root rot, damping-off, and vascular wilts. Common examples include *Fusarium oxysporum*, which causes vascular wilt; *Rhizoctonia solani*, associated with damping-off and root rot; and *Pythium spp.*, known for seedling blight. These pathogens often have a wide host range and produce resilient survival structures such as chlamydospores and sclerotia, enabling them to persist in the soil for years. Traditional management relies heavily on chemical fumigants and fungicides, but these are increasingly restricted due to environmental concerns and resistance development. Thus, leveraging the antagonistic potential of soil microbes provides a more ecologically sound solution.

The life cycle of soil-borne pathogens involves several stages, including spore germination, root penetration, colonization, and symptom expression. Environmental factors such as temperature, moisture, and soil pH significantly influence pathogen activity and disease severity. In addition, pathogen virulence can be modulated by soil nutrient levels and host plant susceptibility. For instance, high nitrogen fertilization often exacerbates diseases like *Fusarium*

wilt. The genetic diversity within pathogen populations also complicates control measures, as different strains may vary in aggressiveness and resistance to treatments. Therefore, an integrated approach that combines knowledge of pathogen biology with soil management is essential for long-term disease suppression. This highlights the need for continual monitoring and adaptive strategies to manage the evolving threat of soil-borne diseases.

3. Role of Soil Microbiome in Disease Suppression

Disease-suppressive soils are characterized by the presence of microbial communities that limit pathogen establishment and disease development. These suppressive properties can be general—due to the overall microbial activity in soil—or specific—attributed to particular antagonistic species such as *Trichoderma*, *Pseudomonas*, *Bacillus*, or arbuscular mycorrhizal fungi (AMF). These beneficial microbes form complex networks and interactions within the rhizosphere, competing with pathogens for resources, producing antifungal compounds, and inducing systemic resistance in plants. The microbiome acts as a barrier, regulating pathogen colonization and virulence through mechanisms like quorum sensing disruption and niche exclusion.

In addition to pathogen suppression, beneficial microbes contribute to overall plant vigor, which indirectly enhances disease resistance. For instance, microbes involved in nitrogen fixation or phosphate solubilization improve nutrient availability, making plants less vulnerable to stress-related infections. The dynamic nature of the soil microbiome allows for rapid adaptation to environmental changes, which can be harnessed to sustain plant health under variable conditions. Furthermore, microbial diversity is often correlated with resilience against disease outbreaks, as diverse communities can provide functional redundancy and ecological stability. High-throughput sequencing and metagenomic approaches have enabled the identification of core microbiomes associated with suppressive soils, providing targets for microbial augmentation and biotechnological applications. Exploring these microbial consortia offers promising avenues for the development of next-generation biocontrol strategies.

4. Soil Health Indicators and Pathogen Proliferation

Soil health plays a pivotal role in determining susceptibility to soil-borne diseases. Key indicators include organic matter content, pH, texture, moisture, microbial biomass, and nutrient availability. Pathogens often proliferate in degraded soils with low microbial diversity and poor nutrient cycling. Conversely, healthy soils with balanced microbial populations and adequate

organic inputs exhibit enhanced disease resistance. The composition and activity of microbial communities can be modulated through crop rotation, cover cropping, organic amendments, and reduced tillage. Assessing soil health through bioindicators such as enzyme activities and microbial respiration offers insights into potential disease outbreaks and helps tailor management interventions.

Recent research emphasizes the importance of biological indicators over traditional chemical or physical parameters in assessing soil health. For example, the presence of specific functional genes associated with nitrogen cycling or antibiotic production can serve as early warning signals of soil health decline or improvement. Additionally, soil structure and porosity affect oxygen availability and water retention, indirectly influencing microbial dynamics and pathogen activity. Practices that enhance soil aggregation, such as organic mulching or mycorrhizal inoculation, can create microhabitats conducive to beneficial microbes. Soil health is not a static attribute but a dynamic state that responds to land use, climatic variability, and management practices. Therefore, continuous monitoring and adaptive management are essential for maintaining disease-suppressive potential in soils.

5. Mechanisms of Microbial Antagonism Against Pathogens

Beneficial soil microbes employ a variety of strategies to suppress pathogens:

- **Competition for Resources:** Microbes compete with pathogens for limited nutrients, especially iron, via siderophore production, depriving pathogens of essential elements.
- **Antibiosis:** Production of antimicrobial compounds such as antibiotics, volatile organic compounds (VOCs), and lytic enzymes directly inhibit pathogen growth. For instance, *Bacillus subtilis* produces iturins and surfactins, while *Pseudomonas fluorescens* synthesizes phenazines and hydrogen cyanide.
- **Parasitism and Predation:** Some fungi like *Trichoderma* directly parasitize pathogens by coiling around their hyphae and secreting cell wall-degrading enzymes.
- **Induced Systemic Resistance (ISR):** Certain microbes activate the plant's defense pathways, enhancing resistance to subsequent infections. Unlike systemic acquired resistance (SAR), which is pathogen-induced, ISR is microbe-induced and associated with jasmonic acid and ethylene signaling.
- **Biofilm Formation:** Microbial consortia often form protective biofilms on root surfaces, shielding plants from pathogen attack and stabilizing beneficial microbe populations.

Additionally, quorum quenching mechanisms are employed by beneficial microbes to interfere with the communication systems of pathogenic bacteria, thereby preventing the expression of virulence factors. Some beneficial microbes also produce enzymes that degrade pathogen cell walls or disrupt spore germination. The spatial organization of microbial communities in the rhizosphere plays a critical role in these interactions, with microscale niches determining the outcomes of competitive and antagonistic behaviors. These mechanisms are not mutually exclusive and often act synergistically to provide robust disease suppression. Understanding the ecological context of these mechanisms is essential for designing effective microbial inoculants and delivery systems in the field.

6. Biological Control Strategies and Applications

Biological control, or biocontrol, refers to the use of living organisms to suppress disease-causing pathogens and enhance plant health. In the context of soil-borne pathogens, this strategy involves the introduction or augmentation of beneficial microorganisms that either directly inhibit pathogens or bolster plant immune responses. Biocontrol agents (BCAs) such as *Trichoderma harzianum*, *Pseudomonas fluorescens*, and *Bacillus subtilis* are among the most widely studied and commercially available for use against soil-borne diseases. These organisms have been found to possess multiple modes of action, including antibiosis, parasitism, competition, and induction of systemic resistance. Formulating these agents into biofertilizers, seed coatings, or soil amendments has become increasingly popular in integrated pest management programs.

Modern biocontrol strategies are increasingly focusing on consortia rather than single-strain inoculants. This approach capitalizes on synergistic interactions among microbial communities, enhancing the robustness and consistency of disease suppression. Advances in genomics and synthetic biology now allow for the customization of microbial consortia with specific traits, such as nutrient solubilization, biofilm formation, and compatibility with host plants. Furthermore, biocontrol agents are being developed with adaptive capabilities to withstand abiotic stresses such as drought or salinity, ensuring their functionality under field conditions.

Despite these advancements, challenges remain in the field-level application of BCAs. Variability in soil conditions, microbial compatibility, and environmental stresses can limit the efficacy and consistency of biocontrol. Moreover, the regulatory landscape surrounding

microbial products often delays commercialization and adoption. To overcome these hurdles, there is a growing emphasis on precision agriculture tools, such as microbial sensors and decision-support systems, that can guide the strategic deployment of BCAs. The integration of biocontrol with other sustainable practices—like crop rotation, organic amendment, and reduced tillage—can further enhance soil health and long-term pathogen suppression. Ultimately, a systems-based approach that considers microbial ecology, plant physiology, and environmental factors is critical for maximizing the benefits of biological control.

7. Advances in Soil Microbiome Engineering

Soil microbiome engineering involves the deliberate manipulation of microbial communities to improve soil health, crop productivity, and disease resistance. This can be achieved through the introduction of **beneficial microbes** (probiotics), modulation of native microbial communities (prebiotics), or habitat manipulation (holobiome engineering). Emerging technologies such as CRISPR-based genome editing, metagenomics, and transcriptomics are enabling scientists to understand and modify microbial functions with unprecedented precision. These advancements have paved the way for designer microbial consortia that can target specific pathogens or modulate plant immune responses.

One of the most promising areas in soil microbiome engineering is the use of microbial inoculants tailored to the plant genotype and local soil conditions. Such specificity ensures higher colonization efficiency and sustained functionality of the introduced microbes. Another exciting frontier is the development of microbial sensors and biosensors that can detect shifts in microbial populations or the presence of specific pathogens, allowing for real-time monitoring and intervention. These innovations are moving the field towards predictive and precision soil health management.

Soil amendments such as biochar, compost, and organic matter are also being engineered to serve as carriers or stimulants for beneficial microbes. These amendments can enhance microbial diversity, improve soil structure, and create a favorable microhabitat for sustained microbial activity. Furthermore, microbial metabolomics—the study of small molecules produced by microbes—offers insights into the chemical dialogues within the soil microbiome and between microbes and plants. Understanding these interactions at the molecular level can inform the design of targeted interventions for disease suppression.

However, the application of microbiome engineering in the field is still in its infancy and faces several bottlenecks, including the complexity of microbial interactions, lack of standardized protocols, and challenges in scaling up from lab to field conditions. Interdisciplinary collaborations among soil scientists, microbiologists, plant pathologists, and data scientists are essential to overcome these barriers. Ultimately, microbiome engineering holds great promise for sustainable agriculture, offering a path to reduce chemical inputs, enhance crop resilience, and restore soil health.

8. Challenges and Future Prospects

Despite the promising potential of soil microbiomes in disease suppression, several challenges impede their widespread application. One major issue is the inconsistency of microbial inoculants under diverse field conditions. Factors such as soil pH, moisture, temperature, and existing microbial communities can influence the establishment and efficacy of introduced microbes. Moreover, the complexity and redundancy within microbial communities make it difficult to predict outcomes and design universal solutions. There's also a lack of standardization in the formulation, quality control, and regulatory approval of microbial products.

In addition, the interactions between soil microbiomes and plants are highly context-dependent, influenced by plant genotype, developmental stage, and root exudate composition. Therefore, a one-size-fits-all approach is unlikely to be effective. To address these challenges, future research must focus on developing tailored microbial consortia suited to specific crops and environments. Integrating microbiome research with advances in soil sensing, artificial intelligence, and machine learning can aid in predictive modeling and personalized soil health management.

There's also a need to explore the role of under-studied microbial groups such as archaea, protists, and bacteriophages in disease suppression. These organisms may hold untapped potential for regulating pathogen populations and enhancing microbial network stability. Additionally, more attention should be given to the ethical and ecological implications of large-scale microbiome interventions. Ensuring the long-term sustainability of such strategies will require careful monitoring, adaptive management, and stakeholder engagement.

The future of soil microbiome research lies in systems-level thinking that combines ecological principles with technological innovations. Collaborative, interdisciplinary efforts will



be key to unlocking the full potential of soil microbiomes in sustainable disease management. With the right investments and policy support, microbiome-based solutions could become mainstream tools in the global effort to achieve food security and environmental sustainability.

Conclusion

The dynamic and intricate relationships between soil microbiomes and soil-borne plant pathogens hold immense potential for transforming agricultural disease management. By harnessing the natural capabilities of beneficial microbes, it is possible to reduce reliance on chemical pesticides, improve soil health, and promote sustainable crop production. This review has highlighted the critical mechanisms of microbial antagonism, the importance of soil health indicators, and the advances in biocontrol and microbiome engineering strategies. While challenges remain, particularly in field application and consistency, the ongoing progress in molecular tools, microbial ecology, and data-driven agriculture offers promising pathways forward. Future efforts must focus on integrating scientific insights with practical management, fostering collaboration among researchers, farmers, and policymakers. Ultimately, soil microbiome-based approaches represent a powerful and ecologically sound solution to mitigate the global threat of soil-borne plant diseases.



LEAF CRINKLE DISEASE IN BLACKGRAM AND GREENGRAM

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Introduction

Vigna mungo is a leguminous crop which is domesticated from *Vigna mungo* var *silvestris* (Lukoki *et al.*, 1980). Blackgram is the fourth most important short duration pulse crop grown in India due to its nutritional quality. It is originated in India. Carbonized seeds of blackgram were found at maheshwar and navdotoli in India prove the India is the centre of origin of blackgram (De candolle 1883). Blackgram is distributed in India, Africa, Iran, Malaysia, Srilanka, USA, Pakistan, Bangladesh, Myanmar, Thailand and west indies. In India Uttar Pradesh, Madhya Pradesh, Punjab, Maharashtra, West Bengal, Andra Pradesh, Karnataka and Tamil Nadu. Blackgram dhal contains 23.4% protein, 1.0% fat, 57.3% carbohydrate and 4.8% fibre. And also rich in Vitamin B, calcium and phosphorus. Not only as a human food and also used as cattle feed. Dried (or) green plants are used as fodder. Blackgram also fix the atmospheric nitrogen act as a mini fertilizer factory and restore the soil fertility. Due to its multipurpose blackgram is cultivated more compare to other pulses. The grain legume production was deteriorated by many insect pest and pathogen. Mungbean Yellow Mosaic Virus, Urdbean Leaf Crinkle Virus, Groundnut Bud Necrosis Virus, Mungbean Leaf Curl Virus were major pathogens affect the crop yield. Urdbean Leaf Crinkle Virus is considered as very severe among the viral disease, and the severity depends on the cultivated varieties and their cropping seasons (Reddy *et al.*, 2005). With this background the review was undertaken to explain the overall aspects of Urdbean Leaf Crinkle Virus.

Symptoms of leaf crinkle disease

The symptoms are mild leaf crinkling, downward leaf curling and mosaic symptoms appeared three weeks after sap-inoculation on the second and third trifoliate leaves. In the field, the first recognizable symptom usually appeared three to four weeks after sowing. Generally, the third trifoliate leaf developed the symptoms first by an increase in the size and turning light green in colour. Considerable malformation of inflorescence was observed in early infected plants. The infected plants started lodging when they attained fourth leaf stage.

Fig 1. Various type of leaf crinkle symptom.



Curling



cupping



Crinkling and Puckering of leaf lamina



Stunting

Vector – transmission of leaf crinkle virus

Generally, one virus known to be transmitted by one group of insects but rather uncommon to be transmitted by several other group of insects . It proves the urdbean leaf crinkle virus may cause by the association of Poty, Tospo and tymo viruses (Biswas *et al.*, 2012).. Generally, viruses transmitted by sap are not transmitted by whiteflies but ULCV is seems to be exception. The disease was transmitted by both sap and insect vectors. It reveals the involvement of more than one strain of ULCV producing the leaf crinkle (sravika *et al.*, 2018).

White fly (*Bemisia tabaci*)

Whitefly is a serious pest of tropical and subtropical regions responsible for transmission of many diseases and cause heavy yield loss (Brown, 1994). *B. tabaci* transmitted, 25-67% of ULCV.

Aphid (*A. gossypii* and *A. craccivora*)

ULCV could be successfully transmitted by two aphid species viz. *A. craccivora* and *A. gossypii* with a short acquisition feeding period of 30 seconds to 2 minutes preceded by a pre-acquisition fasting which was necessary for successful viral transmission (Dhingra, 1975).

Beetle (*H. dodecastigma*)

ULCD is transmitted by *H. dodecastigma* which acts as a vector (Beniwal and Bharathan 1980). The disease is transmitted in a nonpersistent manner.

Seed

Under field conditions, the infected plants grown up from the virus-infected seeds act as primary inoculation for infection and further spread takes place through insect vectors (Gautam *et al.*, 2015).

Environmental influence on urdbean leaf crinkle virus

Some genotypes found resistance at one location turn out to be susceptible at another location. It indicates the environment and genotype interaction should also responsible for disease production (Asfaq *et al.*, 2010). ULCV disease incidence depends upon the host genotypes, growing season and environmental condition (Ashfaq *et al.*, 2008). Maximum ULCV disease incidence was observed at 35-42° C (Max) and 21-19 ° C (Min). And also, no correlation between ULCV disease and relative humidity, windspeed, rainfall. Increasing air temperature increase the disease incidence.

ULCV resistance

Resistance to any virus depends on plant metabolism (Dawson and Hilf, 1992). Development of resistant genotypes is the cheapest source for the management of disease. Selection of resistant genotypes is the major factor for developing resistant variety. Various screening procedures are utilized for select the disease resistant genotypes. Artificial sap transmission, natural infection at field, infector row and mechanical inoculation on seeds were practiced for selecting resistance genotypes. Among the screening methods artificial sap transmission is the effective method. It avoids the escape of genotypes from the infection. Mechanically inoculated plants show symptoms earlier than the other method (Asfaq *et al.*, 2010). According to disease rating scale (Asfaq *et al.*, 2007) genotypes were classified into highly resistant, resistant, moderately resistant, moderately susceptible, susceptible and highly susceptible. Disease rating scale was present in table 2.

Table 2. disease rating scale (0-5) for ULCV

Disease reaction	Disease severity index (DSI)	Reaction
All plants free of symptoms	1	HR
1-10% plants infected showing mild crinkling at the top, pods normal	2	R
11- 20% plants infected showing crinkling and curling of top leaves, pods normal	3	MR
21-30% plants infected with crinkling, puckering, malformation, shortening of pods	4	MS
31-40% plants infected showing all the typical disease Symptoms	5	S
More than 40% plants infected showing all the plants with severe symptoms, few pods containing few seeds	6	HS

Molecular characterization:**Management**

- Use increased seed rate (25 kg/ha).
- Rogue out the diseased plants at weekly interval up to 45 days after sowing. Cultivate seed crop during rabi season.
- Use seeds from healthy plants or certified pathogen free seeds
- Plant tolerant or resistant varieties available in your area
- Monitor your plants or fields for sign of disease vectors
- Remove infected- looking plants and bury them
- Avoid excessive weed growth (weed can serve as alternate host) near your culture
- Use barrier crops such as maize, sorghum and pearl millet to reduce the spread of the disease

- Practice crop rotation with crops that are not suitable to vectors
- Spray Methyl demeton on 30 and 40 days after sowing at 500 ml/ha.
- Seed dressing with imidachlorid 70 WS @5 ml/Kg is usually recommended. Insecticide based on dimethoate can also be used as foliar spray application
- The compound 2,4- dihexahydroxy 1,3, 5 triazine (DHT) hinders the transmission of the virus and increases its incubation period

Conclusion and future prospective:

Blackgram is an important food legume grown throughout the world. High value of lysine makes blackgram an excellent complement to rice in terms of balanced human nutrition. It provides balanced diet, digests easily and produces less flatulence. India is the largest producer and consumer. However, we import the pulse for food purpose. Because both biotic and abiotic stresses reduce the yield. Urdbean leaf crinkle virus reduced the yield drastically compared to other diseases. The virus causing ULCV disease was not yet identified. Genetic mechanism of resistance and inheritance pattern of disease also not yet identified. Molecular characterization is an easy method to identify the resistant gene or resistant locus (QTL). But no molecular works are available for ULCV disease resistance. Increased temperature increases the disease spread. Compared to other major disease (MYMV) ULCV causes higher yield loss. And the disease is easily spread by various mechanisms. More studies are needed to develop the durable resistant varieties to avoid the devastating effect of urdbean.

VALORIZATION OF FISH WASTE FOR RENEWABLE ENERGY: BIODIESEL PRODUCTION

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Abstract

In 2020, global fisheries and aquaculture production reached 232.2 million tonnes, marking a 4.4% increase, with Asia accounting for 70%, followed by Europe and Latin America at 9% each. Seafood exports generate waste, including internal organs, with the industry producing millions of tons of pre-processing waste containing significant fat and oil. The production of biofuel from seafood waste has gained interest due to circular economy principles and sustainable energy demand. This technical article explores methods of extracting biodiesel from seafood waste through biochemical techniques. It examines the advantages, environmental benefits, and challenges of biofuel production from waste. The technical article highlights seafood waste's potential for bioenergy within the circular economy, with future research aimed at developing more efficient production technologies.

Keywords: Seafood Waste, Extraction, Conversion Methods, Environmental impact, Future scopes

Introduction

The rapid exhaustion of non-renewable energy resources has emerged as a critical challenge, driving a shift towards sustainable alternatives. Fossil fuel combustion has released carbon dioxide and other substances into the atmosphere, altering Earth's climate and increasing ocean acidity (Nizar et al., 2021). Since the Industrial Revolution, fossil fuel use has increased atmospheric carbon dioxide by 43%. This reliance has caused pollution and climate change,

leading to health issues including respiratory disorders, cardiac arrests, cerebrovascular events, and increased mortality. Biofuels now account for 3.4% of global transportation fuel. Biomass-derived bioenergy helps mitigate global warming through its carbon-neutral combustion cycle, as plants absorb carbon dioxide during photosynthesis. Biofuels come from biological sources like bacteria, plants, animals, and waste materials. Solid and liquid biofuels are widely used due to their abundance and cost-effectiveness. Unlike fossil fuels that take millions of years to form, biofuels can be rapidly produced. First-generation biofuels from food crops present challenges, including price increases, limited emission reductions, and high land requirements. Corn demand increases affect soybean and wheat prices by 40%, 20%, and 17%, respectively (Datta et al.,2019). Fish waste biofuels offer a promising alternative without affecting climate patterns. We examine biofuel extraction methods from seafood waste, assess production benefits, and analyze challenges in seafood waste biorefineries.

Biodiesel from Seafood Waste

Seafood waste shows promise for biofuel production due to its availability and high fatty acid content, serving as an alternative to conventional sources while reducing emissions and promoting sustainability. Its biochemical composition of low protein and high fatty acids makes it an efficient biofuel feedstock. Global fish production reached 242 MT in 2023, with 75% for human consumption and 25% for non-food purposes. The global seafood market is projected to reach 732.87 billion USD with 174 MT production. Processing plant waste constitutes 40-65% of processed fish, impacting the environment. Sardine, mackerel, and tuna are the main oily fish in the canning industry, with sardine processing generating substantial waste. Seafood-based biofuels offer advantages over fossil fuels through carbon absorption and blending, reducing atmospheric emissions. The conversion of seafood waste to biofuel creates a balance where carbon released during combustion is offset, resulting in near-zero net emissions. Fossil fuel use in transportation and energy production contributes to global warming. Biofuels like biodiesel, bioethanol, and biogas can mitigate climate change by reducing fossil fuel reliance. Fish processing waste pollutes aquatic ecosystems but can be repurposed for biofuel production, enhancing energy security and reducing environmental risks. Developing biodiesel and biogas from fish waste is crucial for sustainable development in the renewable energy sector.

Biodiesel Production

Fatty acid methyl esters (FAME), monoalkyl esters from long-chain fatty acids, are a

common biodiesel component. These esters can be sourced from renewable lipids, such as sunflower, palm, soybean, rapeseed, canola, jatropha, and cottonseed, but are generally more expensive than traditional diesel. There is interest in alternative sources for biodiesel production, including non-edible vegetable oils, used cooking oil, and oil from seafood waste (Aien & Mahdavi, 2020). Converting seafood waste into biodiesel involves oil extraction and transesterification. Producing three moles of methyl esters and one mole of glycerol requires three moles of alcohol per mole of triglyceride. While various alcohols can be used, methanol is preferred for its cost-effectiveness and properties in commercial production. Acids, bases, or lipase enzymes can catalyze the reaction. Al Azad et al. (2019) found that fish waste components were traditionally used for fishmeal production but noted their fatty acid profile suited biodiesel production. Crude oils were extracted using petroleum ether and methylated to produce fatty acid methyl esters. Ghaly et al. (2010) highlight fish waste's potential as a sustainable raw material for biodiesel, meeting growing renewable energy demands.

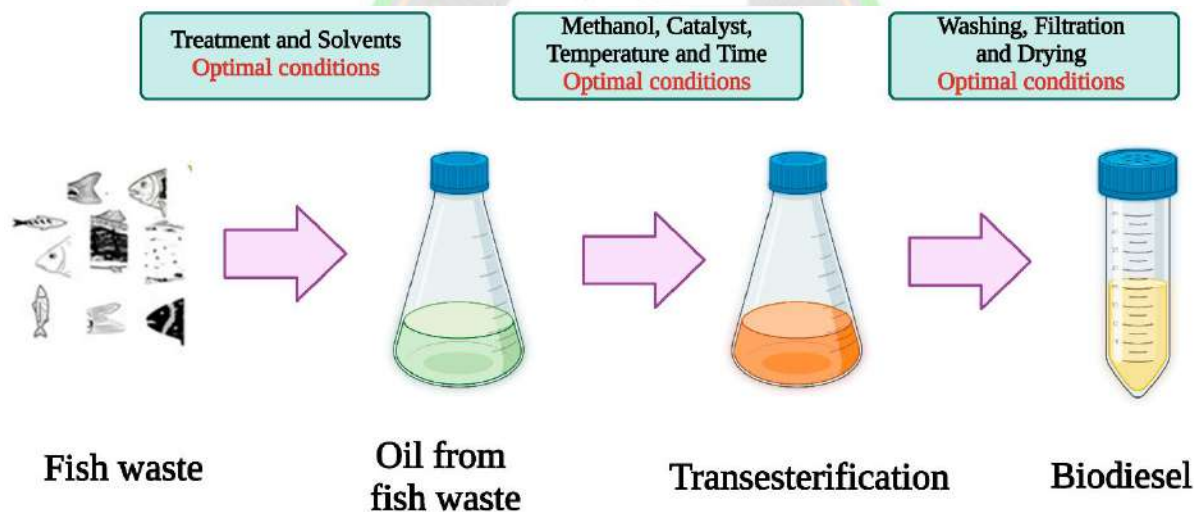


Fig. 1. Production of Biodiesel from Fish Waste

Enzymatic Hydrolysis

Immobilized lipase enzymes convert fish oil into biodiesel through enzymatic hydrolysis and transesterification, utilizing a low alcohol-to-oil ratio and a cool reaction temperature. Unlike chemical catalysts, which require multiple pretreatment stages for feedstocks with free fatty acids (FFA) above 0.5%, enzyme catalysts can produce biodiesel without prior preparation and can be reused to lower costs. Enzyme immobilization facilitates the recovery of expensive enzymes (Tan et al., 2010). The enzyme solution was prepared in a pH 7 phosphate buffer, and

immobilized lipase was formed by mixing activated carbon with the enzyme solution, which was agitated for 24 hours at room temperature. After equilibration, the immobilized lipase was filtered using Whatman paper. The feedstock oil was combined with methanol and water. Immobilized *Aspergillus niger* lipase was added to this mixture, which was maintained at 30-50°C in an orbital shaker at 200 RPM for 10 hours. Enzymatic transesterification generally takes between 4 and 72 hours. Key factors influencing biodiesel production include temperature, water content, and methanol-to-oil ratio, with optimal values varying based on the immobilization method, lipase source, and feedstock (Arumugam et al., 2017). Pinyaphong et al. (2011) utilized fish oil from discarded parts with *Carica papaya* lipase, achieving an 83% methyl ester yield under optimal conditions: a 1:4 oil-to-methanol ratio, 20% lipase, 0.23 water activity, and 20% tert-butanol at 40°C after 18 hours. Ward et al. (2011) observed that enzymatically producing fatty acid methyl esters from waste fish oil offers economic and environmental advantages. However, due to stringent sanitation requirements to prevent contamination, enzymatic hydrolysis faces challenges in competing with petroleum fuels.

Environmental impact: Biofuel vs conventional diesel

Efforts have been directed towards transforming seafood byproducts into biofuels, given their substantial oil content and the swift rate of fish production. Mixing fish waste with traditional diesel has become cost-effective, decreasing reliance on fossil fuels and lowering CO₂ emissions. Nonetheless, refining oil extraction techniques and maintaining the quality of raw materials present considerable challenges in developing biorefineries. Key issues include preserving waste, finding suitable locations, and the absence of efficient distribution networks. Additional challenges stem from selecting fish species and the bacterial conversion of polysaccharides. Scaling up biotechnological processes remains a significant obstacle, and despite laboratory advancements, immediate practical application is still uncertain. Seafood waste offers distinct benefits over other feedstock sources for sustainable biofuel production. Previously, seafood waste was either used in poultry feed or improperly disposed of, with its potential for biofuel largely untapped.

These biofuels are carbon-neutral, helping to reduce atmospheric CO₂ emissions and potentially alleviating global warming. Utilizing seafood waste diminishes pollution and fosters cleaner environments while also reducing fuel costs. However, there are drawbacks, such as seasonal variations in fatty acid content and susceptibility to spoilage. Preservation strategies

must prevent microbial degradation, which adds to energy and transportation expenses. Converting seafood waste necessitates enhanced extraction of organic content through physical or chemical means. Producing biofuels from marine waste remains costlier than other biomass sources due to the expenses of pretreatment, transportation, and bioreactor operation.

Conclusion

The creation of third-generation biofuels using seafood waste offers promising potential. The effectiveness depends on elements influencing biomass characteristics and extraction methods. Improving oil extraction from seafood byproducts will enhance waste collection. Producing fuel from fish waste can be environmentally sustainable, cost-efficient, and renewable. To achieve this, comprehensive research efforts should be coordinated globally. These initiatives can reduce land pollution and decrease harmful emissions from biofuel-powered engines.

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CLIMATE SMART SILVICULTURE: FUTURE OF FOREST MANAGEMENT

Article ID: AG-VO5-I06-35**Ravi Raja Simman. P^{1*}, Dr. B. Sivakumar² and Sri Venkateshwaran. M³**

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Abstract

Forests are global carbon sinks, storing 7.6 billion metric tons CO₂ per year and provide ecosystem services like climate regulation, hydrological stability and biodiversity maintenance. Climate change, in the form of higher temperatures, CO₂ in the atmosphere, changed precipitation and more frequent disturbances is affecting forest productivity and health. Traditional silviculture which has focused on wood production is no longer effective in coping with climate variability. Climate-smart silviculture (CSS) is a multi-faceted forest management approach that combines adaptation, mitigation and resilience principles. CSS selects site-specific species, assisted migration and structurally and functionally diverse stand design to insulate forests from environmental pressures. Predictions from ecologic niche modelling and artificial intelligence driven simulations help practitioners to forecast growth, carbon sequestration and silvicultural treatment adaptation to future climates. The Composite Climate-Smart Index (CSI) is a good indicator to measure the environmental and socio-economic impact of CSS interventions. CSS implementation is however limited by institutional, regulatory and property issues. Integration into policy and focused investment is key to scaling up CSS in different landscapes. As recent studies show, CSS is an urgent paradigm shift, aligning forest management to climate resilience and carbon neutrality. It will not just require scientific innovation but more importantly collective action from foresters, ecologists, policy-makers and technology

developers. The synthesis emphasizes the importance of CSS in ensuring forest ecosystem sustainability in the face of rapid climate change.

Keywords: Forests, Climate Smart Silviculture, Forest Management, Global Carbon Sink, Climate-Smart Index

Introduction

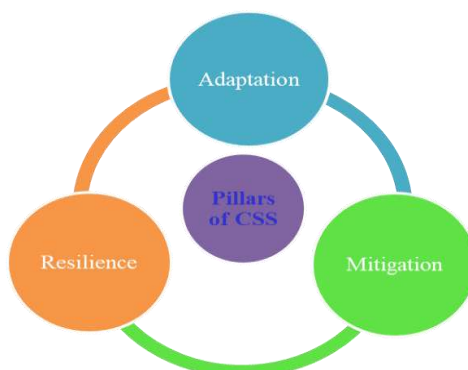
Forests are among the earth's most important terrestrial carbon sinks, storing around 7.6 billion metric tons CO₂ per year. They deliver ecosystem services including climatic regulation, hydrological stability, and biodiversity conservation. Yet, these systems are under intensifying threat. Global warming, atmospheric CO₂ elevation, extreme weather, and modified disturbance regimes are degrading forest structure and function.

Silviculture is the art and science of growing tree crops for subsistence, commercial, social and ecological benefits. Silviculture means, maintaining forest stands towards sustainability over the long term, has traditionally focused on timber production, paying relatively little heed to resilience under climatic variability. Given present and future climatic trends, there is growing interest in the notion of climate-smart silviculture (CSS). Based on Climate-Smart Forestry (CSF) principles, CSS synchronizes forest management in compliance with adaptation to climate change, carbon reduction, and resilience (Wang et al., 2024).

Conceptual Foundations for Climate-Smart Silviculture

Climate-smart silviculture can be characterized as a dynamic, systems-focused forest management regime that incorporates, by design, adaptation to the changed climate, greenhouse gas reduction, and the promotion of resilience. Distinguishing it from static regime principles, CSS acknowledges uncertainty and variability in the ecosystem as key components to be factored into planning.

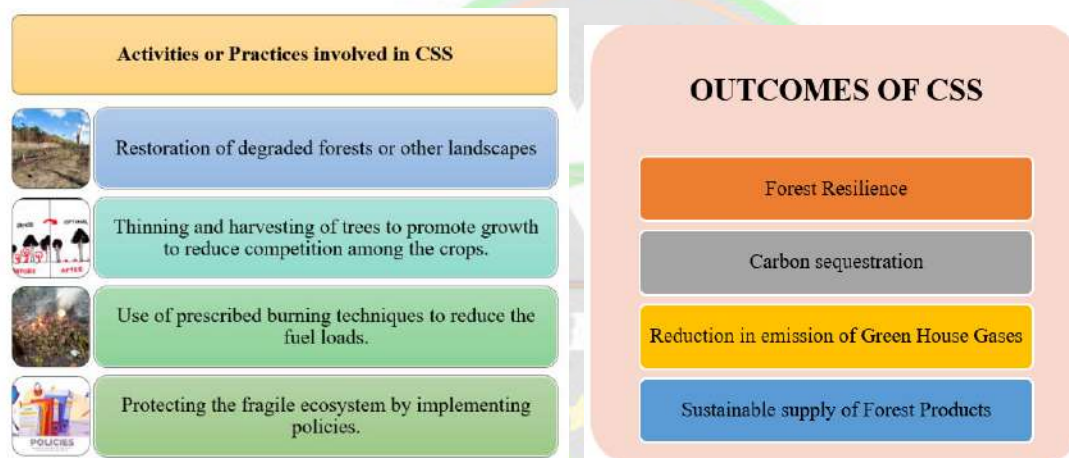
As per Alfieri et al. (2024), there are three pillars undergirding CSS:



1. **Adaptation:** Improving the resilience of forest ecosystems to handle existing and potential future climatic stresses.
2. **Mitigation:** Enhancing net carbon storage through enhanced management practices.
3. **Resilience:** Maintaining forest ecosystem services through functional and structural diversity.

Thus, Climate Smart Silviculture is defined as “An emerging approach in Forest Management that focuses on managing forests and/or trees outside forests to adopt and to mitigate climate change in long term basis, while also supporting other forest-based goods and services like wood production, and Biodiversity Conservation.”

CSS, therefore, redirects silviculture towards multifunctional, climate-responsive outcomes, blending ecology, technology, and socioeconomic integration.



Species Selection and Assisted Migration

An important aspect of CSS is the choice of forest species which are expected to survive and perform under the expected climatic conditions. A conventional approach to this is through historical range schemes, which is no longer considered prudent, particularly as temperatures and humidity levels vary across latitudes and altitudes. Luo et al. (2025) highlight the significance of using species-site matching models to calculate long-term viability for different tree species under multiple scenarios of climate. Their assessment in China integrates ecological niche model outputs along with carbon sequestration potential to rank species that can provide double advantages through their adaptability and mitigation potential. Incorporating assisted migration-human-aided relocation of species into favourable places is another proactive strategy under CSS frameworks.

Encouraging Structural and Functional Diversity

One of the strongest such results across the science of climate adaptation is the fact that more diverse forests are more resilient. Diversification adds functional redundancy, buffer capacity, and response diversity—factors that make up an ecosystem's capacity to recover from disturbance. Caselli and Bava (2025) present a detailed case study on how Central European silvicultural methods can be used on native forests in Patagonia. Their data show that structurally complex stands consisting of mixed species and mixed-age trees had higher resistance to windthrow, drought, and fungal infections. These observations justify shifting from monocultures to more heterogeneous stands, which can be more supportive of ecosystem services under climate change.

Technological and Analytical Breakthroughs

Climate-smart silviculture is more and more based on data analytics, remote sensing, and artificial intelligence to guide and optimize decisions. Wang et al. (2024) present an artificial intelligence-powered model that simulates forest growth, carbon flux, and species competition across several future climatic scenarios. Through this, it is possible to make adaptive planning, test scenarios, and conduct cost-benefit assessment both at the landscape and the stand level. These technologies enable managers to modify planting densities, canopy gaps, thinning cycles, and rotation harvests based on ongoing monitoring and long-term simulations – marking the dawn of precision silviculture.

Indicators and Assessment Metrics

The assessment of climate-smart performance needs to be supported by strong indicators. Alfieri et al. (2024) suggest using a Composite Climate-Smart Index (CSI), integrating ecological indicators (species richness, carbon stock, etc.) and socio-economic indicators (labor inputs, economic yield, and reduction of risks, etc.). The CSI provides an adaptive yet stringent methodology to monitor progress and to underpin funding, policy, and certification programs. This is in line with the emerging trend towards evidence-based forestry, whereby management effectiveness is calculated quantitatively and not through heuristic or tradition-driven methods.

Governance and policy dimensions

Notwithstanding advances in science, the large-scale application of CSS is confronted by institutional and policy issues. Gregor (2024) underlines divergences among EU countries in moving towards climate-smart forestry due to disparate regulations, fragmented property

ownership, and differing levels of public participation. They advocate for integrative policy instruments that combine climate, forestry, and land-use agendas under unified legislative frameworks. International initiatives such as the EU Forest Strategy and REDD+ serve as a foundation, but subnational and national implementation is still paramount. Climate finance, public-private partnerships, and capacity building are key to converting concepts under CSS into transformations at the field level.

Conclusion

Climate-smart silviculture is no silver bullet, yet it is an essential rebalancing of our perception, stewardship, and valuing of forests in the age of uncertainty. Through embracing the complexities of nature, using the latest technologies, and building adaptive institutions, CSS can transform forests into dynamic, resilient, and high-performing landscapes. As the impacts of climate change grow in their severity, the need for CSS-informed policy, research, and practice cannot be overemphasized. In the future, interdisciplinary partnerships among ecologists, foresters, data scientists, and policy makers will be crucial to ensuring that our forests not only endure but flourish in an ever-changing environment.

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QUEEN'S ELIXIR - ROYAL JELLY

Article ID: AG-VO5-I06-36**Nithya Shri, C. M., Nasiha. I., Prithika. V., S.Suganya Kanna, S.Prabhu and K.Kalpana**

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Introduction

Honeybees produce various substances, each serving distinct purposes within the hive and offering unique benefits to humans. These include honey, beeswax, propolis, bee pollen, and royal jelly. Among these, royal jelly stands out due to its pivotal role in determining the development of a queen bee. While all larvae are initially fed royal jelly, only those destined to become queens continue to receive it, leading to significant differences in morphology and longevity compared to worker bees.



Royal jelly

Harvested from the heart of the hive, Royal Jelly is a rare, nutrient – rich superfood produced exclusively for the queen bee. Packed with essential vitamins, amino acids, and antioxidants, this creamy, golden substance is nature's way of supporting energy, immunity and youthful vitality. Royal jelly is a creamy, yellowish-white hypopharyngeal glands of worker bees. It's used to feed bee larvae, particularly the queen bee, and is rich in nutrients.

Composition and Significance

Royal jelly is composed of approximately 67% water, 12.5% proteins (notably major royal jelly proteins or MRJPs), 11% simple sugars, 6% fatty acids, and 3.5% 10-hydroxy-2-decenoic acid (10-HDA). It also contains trace minerals and vitamins, contributing to its nutritional value. The exclusive feeding of royal jelly to selected larvae triggers the development of queen bees, influencing their size, fertility, and longevity.

Production of Royal Jelly by Bees

In a honeybee colony, worker bees, specifically nurse bees (young worker bees aged 5–15 days) are responsible for producing and exhibiting (delivering) royal jelly to feed the larvae and the queen. Here's how this works in a near, natural manner inside the hive:



1. Production of Royal Jelly:

Nurse bees have hypopharyngeal glands and mandibular glands in their heads. These glands produce a thick, milky-white substance called royal jelly, which is protein-rich and packed with vitamins, sugars, and lipids.

2. Secretion Process:

When needed, the glands secrete royal jelly directly into the bee's mouthparts.

3. Delivery of Royal Jelly:

The nurse bee moves close to the brood cells (Hexagonal wax cells) where larvae are kept. The bee bends its head into the cell and deposits the royal jelly around and beneath the young larvae. All bee larvae (worker, drone, queen) are fed royal jelly for the first 2–3 days of their life. After this, only the future queen larva continues to receive royal jelly in large quantities throughout her larval development.

4. Special Queen Cells:

Queen larvae are housed in special vertical cells called queen cells. These cells are flooded with royal jelly to ensure continuous, exclusive nutrition for the developing queen bee.

Importance of Royal Jelly

- ❖ The constant and exclusive feeding of royal jelly triggers a hormonal and genetic expression change in the queen larva.
- ❖ This leads to her becoming sexually mature, capable of laying thousands of eggs .
- ❖ Nurse worker bees produce royal jelly in their head glands, move near brood cells, and deliver the royal jelly by directly secreting it into the cells containing the larvae especially in larger quantities for future queen larvae in queen cells.

Methods of Royal Jelly Extraction

Harvesting royal jelly is a meticulous process that requires careful manipulation of bee colonies. The primary methods include:

1. Traditional Grafting Method (Standard Queen Rearing Technique)

This is the most common and reliable method used by commercial beekeepers.

- Queen removal: The existing queen is removed from the hive to induce queen-rearing behaviour.
- Grafting larvae: Worker bee larvae aged 12–36 hours are transferred (grafted) into artificial queen cell cups using a grafting tool.
- Queen cell frame: These grafted cups are fixed onto bars and placed inside the hive (usually a queenless starter colony).
- Royal jelly secretion: Nurse bees, stimulated by the queenless condition, begin feeding the larvae with royal jelly.
- Harvesting: After 68–72 hours (before the larvae consume most of the jelly), the larvae are removed and the royal jelly is collected using a spatula or suction device (preferably plastic or glass to avoid contamination).

2. Non-Grafting Method

This method eliminates manual grafting and is suitable for small-scale or beginner beekeepers.

- Specially designed non-grafting frames or cups are used, often with queen pheromones or worker larvae already embedded.
- Colonies are stimulated similarly (usually made queenless or queen-right with confined queens).

- Bees naturally deposit royal jelly into pre-designed cups without needing human grafting.



3. Queenless Colony Method

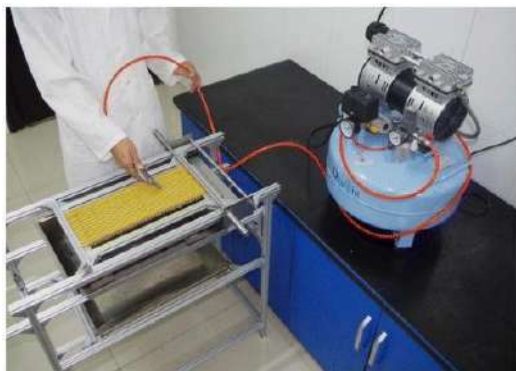
A dedicated hive is maintained without a queen to ensure continuous production.

- The queen is permanently removed from a strong colony.
- Artificial queen cups are introduced containing young larvae.
- The colony, in its continuous effort to rear queens, fills these cups with royal jelly.
- Royal jelly is harvested every 3 days, with new larvae introduced each cycle.

4. Ultrasound-Assisted Extraction (UAE)

This modern laboratory technique is used to isolate and concentrate bioactive compounds from royal jelly.

- Royal jelly is subjected to ultrasonic waves in a solvent medium.
- This enhances the breakdown of jelly cells and facilitates the release of active compounds like 10-HDA.



- Often used in pharmaceutical and cosmetic industries for extract standardization.

NUTRITIONAL VALUE

Proteins: Royal jelly contains proteins, including **Royalactin**, which is believed to have unique properties.

Vitamins and minerals: It's a good source of B vitamins, vitamin C, and minerals like calcium and potassium.

Fatty acids: Royal jelly contains fatty acids, including 10-hydroxy-2-decenoic acid (10-HDA), which is thought to have antimicrobial properties.

POTENTIAL HEALTH BENEFITS

Anti-aging: Some studies suggest that royal jelly may have anti-aging properties, although more research is needed.

Immune system support: It may help support the immune system and reduce skin inflammation.

Skin and wound healing: It's sometimes used in skincare products due to its potential benefits for skin health and wound healing.

However, it's important to note that while royal jelly is used in various applications, scientific evidence supporting its efficacy for these uses is limited, and more research is needed to substantiate these claims.

Conclusion

Royal jelly is a unique and vital substance within the beehive, playing a crucial role in the development of queen bees. Its extraction requires specialized techniques and careful handling to maintain its quality. While it has been utilized in various industries and traditional practices, further scientific research is necessary to fully understand and validate its potential benefits for human health.

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MACHINE LEARNING ALGORITHMS USED IN SPECTROSCOPY FOR FOOD QUALITY ANALYSIS

Article ID: AG-VO5-I06-37**Ulaganathan Arisekar*¹, Balasubramanian Sivaraman¹, Rajendran Shalini¹**

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Abstract

Spectroscopic techniques (STs) supported by machine learning (ML) have evolved as transformative tools for analyzing food quality and safety. STs are effective for food quality evaluation due to their non-destructive, rapid analysis of biological components. This technical article examines ML models' application to spectroscopic data for assessing food safety and quality. STs, including Raman spectroscopy (RS), hyperspectral imaging (HIS), mid-infrared (MIR) spectroscopy, terahertz (THz) spectroscopy (THzS), and near-infrared (NIR) spectroscopy, generate complex datasets that require machine learning (ML) tools for practical analysis. ML accurately identifies patterns and quality parameters using controlled, uncontrolled, and deep learning methods. The part discusses machine learning (ML) algorithms, including support vector machines (SVM), Random Forest Regression Model (RFR), neural network models (CNN), principal component analysis (PCA), and deep convolutional networks, with a focus on identifying adulterants and predicting food shelf life. It addresses data processing challenges, ML model optimization, and application in food quality assessment, guiding scientists and food industry operators using STs and ML to improve food safety.

Keywords: Spectroscopy, Machine Learning, Algorithm, SERS, CNN, Food Quality Analysis

Introduction

Spectroscopy is widely used for assessing food quality and safety. Various techniques

include Raman, near-infrared (NIR), FTIR, fluorescence, infrared (IR), and UV-VIS. NIR spectroscopy is popular for food evaluation due to its sensitivity to C-H, O-H, and N-H bonds (Tian et al., 2023). RS identifies molecular structures through inelastic photons. Fluorescence spectroscopy measures changes in fluorescence signals of food components (Gorji et al., 2022). IR spectroscopy with chemometrics has become vital for food quality assessment. THz spectroscopy uses short-pulse radiation for quality analysis. Spectral data interpretation assesses food quality by understanding its relationship with food composition. Artificial intelligence enables automated spectrum analysis, eliminating subjective interpretation (Xu et al., 2021). Machine learning in food quality analysis has advanced through improved data analysis and processing techniques. ML-equipped spectroscopic techniques establish connections between spectral data and quality parameters. Spectral data reveals chemical information about food quality and origin. ML-assisted spectroscopic technologies are extensively used for agri-food product analysis. Spectroscopy provides quick, nondestructive food quality and composition analysis through light-material interaction. Traditional analysis requires extensive sample preparation and chemicals, while spectroscopic methods enable efficient real-time monitoring during food processing.

Fundamental Ideas in Spectroscopy for Food Analysis

- ✓ Spectroscopy measures light absorption, emission, and scattering to determine the molecular composition and structure of food matrices. The wavelength range and interaction type determine the spectroscopic methods used.
- ✓ UV-Vis spectroscopy measures light absorption in the UV and visible regions, detecting food colourants, pigments, and antioxidants to assess concentrations of polyphenols and vitamins.
- ✓ NIR spectroscopy evaluates light absorption within 780-2500 nm, measuring food moisture, protein, fat, and carbohydrate content, particularly in cereal, dairy, and meat sectors. FTIR spectroscopy identifies molecular vibrations through infrared radiation absorption, explaining functional groups and monitoring food adulteration and lipid oxidation.
- ✓ Raman spectroscopy uses inelastic light scattering to detect structural changes and adulterants. Fluorescence spectroscopy excites molecules with UV or visible light, identifying proteins and vitamins for quality assessment. Spectroscopic methods are

applied across food sectors to preserve quality and detect contaminants in milk, oils, and spices.

- ✓ Key applications include:
 - Nutritional Analysis of food composition
 - Shelf-Life Monitoring
 - Geographic origin verification
 - Microbial contamination detection
 - Food adulteration and defect detection
 - Real-time quality monitoring
- ✓ Combining spectroscopy with machine learning transforms food quality assessments, though high costs and the need for qualified personnel limit adoption. The development of affordable instruments will likely expand field applications to ensure food quality and safety.

ML in Spectroscopy and Quality Analysis

Machine learning is a branch of artificial intelligence that runs algorithms by retrieving data from sources. Two main types exist: supervised learning using labelling and unsupervised learning without labelling. Machine learning is extensively used in chemical data analysis to replace human work, particularly using supervised learning algorithms to visualize compounds. Spectroscopic analysis analyzes chemical data based on light wavelength, focusing on the interaction between chemical matter and electromagnetic rays. This technique studies compounds' structures and functional groups, where compounds absorb energy near the UV range due to electronic transitions. Machine learning is crucial in spectroscopic analysis, particularly for wavelength selectors (monochromators) that choose appropriate wavelengths for samples. The detector then analyzes and graphs compounds. Supervised learning algorithms are common in spectroscopy as the system labels chemical compounds, matching new compounds with existing database information.

Machine learning algorithms minimize noise from environmental, trace elements, temperature, and instrumental interference. These algorithms are essential for accurate analyte identification and integrating spectra. While manual integration may cause errors in selecting absorbed light intensity, machine learning eliminates these mistakes. With modern spectroscopic technology, the system incorporates absorbance formulas into its algorithm, displaying results

digitally. Machine learning tools advance analytical techniques, reducing human error and enhancing chemical composition accuracy (Worsfold et al., 2017).

ML Algorithms Used in Spectroscopy

Machine learning includes supervised and unsupervised approaches, which are explained in the following sections. Table 1 presents commonly employed algorithms in machine learning spectroscopic methods and their advantages.

Table 1. Machine Learning Algorithms Used in Spectroscopy with Applications

ML Algorithm	Spectroscopy Technique	Application
Support Vector Machine (SVM)	NIR, FTIR	Classification of food quality, disease detection in plants
Random Forest (RF)	Raman, UV-Vis	Material identification, pollution monitoring
Principal Component Analysis (PCA)	NMR, FTIR	Dimensionality reduction, exploratory data analysis
Partial Least Squares Regression (PLSR)	NIR, UV-Vis	Quantitative analysis in pharmaceuticals
K-Nearest Neighbors (KNN)	Raman, NIR	Pattern recognition in chemical spectra
Artificial Neural Networks (ANN)	FTIR, UV-Vis	Spectral pattern recognition, drug analysis
Convolutional Neural Networks (CNN)	Hyperspectral Imaging	Image-based classification in agriculture
Gradient Boosting Machines (GBM)	UV-Vis, FTIR	Prediction of chemical concentrations
Deep Belief Networks (DBN)	NIR	Non-linear spectral feature learning

ML for Sensory Quality Assessment

Food product quality is evaluated based on physical attributes, chemical composition, microbial and toxic contaminant levels, and sensory characteristics. Consumers globally demand consistent high-quality food products. Sensory quality assessment techniques gauge product

quality. Quality parameters include physical and functional properties, nutritional content, organoleptic features, and adulterants. Product safety is determined by examining microbial contamination and chemical components. Machine learning (ML) tools have replaced human supervision with other models (Mitchell et al., 1995). These ML models verify physical attributes such as appearance, texture, color, viscosity, turbidity, and imperfections in food items. It is not necessary to input extensive information or guide the machine to perform its tasks. The history of computer evolution and troubleshooting is available in resources. Machine learning, within artificial intelligence, is expanding across sectors to address various problems. This enables machines to learn independently and acquire knowledge of troubleshooting using diverse methodologies. In quality assurance, ML tools perform specific tasks and provide accurate solutions according to GxP principles.

Conclusion and challenges

This section explores integrating spectroscopy and machine learning (ML) for food quality assessment, providing quick non-invasive analysis. ML model precision depends on spectral data quality, sample preparation, and environmental conditions. Consistent conditions and dataset calibration are essential. Portable spectroscopy aids data collection, though variability affects database management. Collaborative research accelerates dataset development. Food structure complexity requires further study (Feng et al., 2021). Understanding ML models is vital for decisions. Interpretable spectroscopic techniques remain challenging. Unsupervised ML models see limited use in food quality analysis. High computational needs restrict applications, requiring efficient real-time models. IoT and ML enable onsite detection. Data pre-processing reduces variability. Spectroscopic techniques need accuracy improvements. Domain-specific ML models are essential for food matrices, considering constituents and molecular interactions.

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THE SECRETS OF STINGLESS BEES

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Introduction

Stingless bees (*Tetragonula iridipennis*) are the smallest honey producing bees belonging to the family Apidae and subfamily Meliponinae. In India these are widely known as dammar bees. The sting of the dammar bee is vestigial. As a mode of defence action, they bite their enemies or intruders and is different from the four species of genus *Apis* in appearance and habits. Like honeybees they are highly social insects, living in colonies. The colonies of stingless bees are perennial in nature and usually consist of hundreds or thousands of workers. They make their nests in dark places like empty logs, cavities in tree trunks, cracks and crevices in old walls etc., where the nest entrance mostly projects as an external tube. They prefer closed structure for nesting rather than open space. Unlike the honeybees of the genus *Apis*, stingless bees use to keep their honey and pollen in spherical pots separately, prepared by using a mixture of wax, resin/propolis and mud called as “cerumen”. The larval feeding process of stingless bees also differs from that of the honeybees of genus *Apis*. These bees are important pollinators of various food crops and can be domesticated in hives.

Beekeeping with stingless bees is called “meliponiculture”. The speciality of the stingless bees is the ability to pollinate small-sized flowers due to their diminutive figure which cannot be achieved by the relatively big honey bees and other wild bees. As well as, stingless bees are true generalists, collecting nectar and pollen from a vast array of plants. On the contrary they lack functional sting, which makes them suitable especially for pollination of crops that are cultivated in inhabited areas and in enclosures such as cages and greenhouses. The use of stingless bees as

pollinators has opened a new economic possibility for meliponiculture. Thus keeping in mind the importance of pollination benefits as well as honey quality which is mainly used in medicinal purpose.

STINGLESS BEES IN INDIA

From North East, North, and South India, it has been reported two genera and six different species of stingless bees: *Lepidotrigona arcifera*, *Tetragonula bengalensis*, *Tetragonula iridipennis*, *Tetragonula laeviceps*, *Tetragonula praeterita* and *Tetragonula ruficornis* and described five species of *Tetragonula*, namely, *Tetragonula vikrami*, (from Karnataka), *T. sumae*, (from Tamil Nadu), *T. ashishi* (from Maharashtra), *T. shishirae* (from Rajasthan) and *T. shubhami* (from Chhattisgarh).

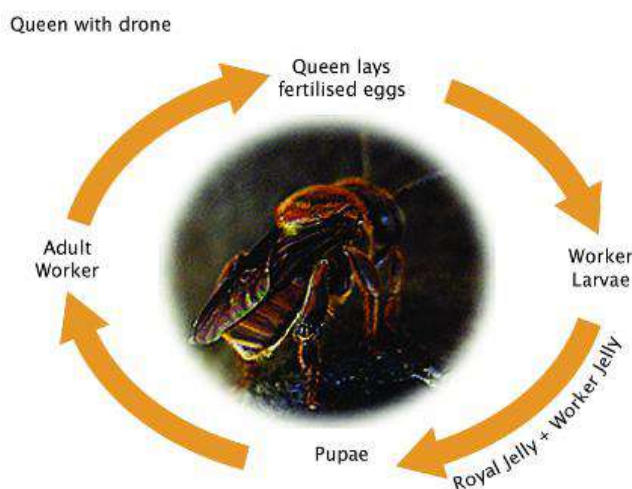
DESCRIPTION AND IDENTIFICATION

Like other bees in its sub-species group, *T. iridipennis* can be identified by its dark mesoscutum or middle thorax region with four distinct hair bands separated by broad glabrous interspaces. It can be further distinguished from other species in its sub group by its chestnut-brown colored mandible which does not have a black apical area and a few dark brown erect setae or hair-like structures on the margin of its scutellum. Other species in the subgroup have yellow mandibles which have black apical areas and have light colored setae on their scutella. Based on studies of workers, *T. iridipennis* has a total body length ranging from 3.5 to 4.0 mm and an entire body which is black to blackish brown. Size differences as well as male genitalia are key for identifying the species. They are relatively small sized bees and the male penis valve is very robust and tapers only at the apex. Male genitalia are also key to differentiating between male and female bees because the two sexes are very similar in size and color.

DISTRIBUTION

T. iridipennis is a tropical bee species and is found throughout the Indo-Malay region. Its range was once thought to go as far as the Solomon and Caroline islands, but unlike other *Tetragonula* species, its range is fairly limited. Although it was originally discovered on the island of Sri Lanka, it is predominantly found in India. Specifically, studies have been conducted on *T. iridipennis* colonies located in Karnataka, Kerala, and Tamil Nadu. *T. iridipennis* also occurs on the islands of Indonesia where it is a natural pollinator.

LIFECYCLE



MATING BEHAVIOUR

Like males in other stingless bee species, there is tremendous competition between *T. iridipennis* males to copulate with virgin queens. Males have been observed to form large aggregations and to engage in mass flights near nests waiting for the emergence of virgin females. Once a virgin queen emerges, it pairs with one of the males and a mating flight ensues, resulting in the fertilization of the queen.

COLONY CYCLE

As with other highly eusocial bee species, *T. iridipennis* colonies are founded by swarming. However, this process is different for stingless bees like *T. iridipennis* and honey bees. In honeybees, the process is abrupt and a large group of workers leaves the original colony with the old queen, thus few connections are maintained between the old and the new colonies. The process is more gradual for stingless bees such as *T. iridipennis*. First scout workers from the original nest find a new nesting site and gradually transport resources there from the mother colony. A virgin queen from the mother colony then arrives usually accompanied by a mass of workers.

Common nesting sites include tree trunks, logs and wall cavities. The nests are relatively low to the ground and are constructed at heights between 1.93 meters and 2.2 meters from the ground. Nests tend to be dark brown in color in order to blend in with their surroundings. The Indian tree species *Cycas sphaerica* appears to be an important nest provider for *T. iridipennis*.

STAGES OF STINGLESS BEE SWARMING

- **Reconnaissance and preparation:** Scouts inspect potential new nest sites for suitability, considering factors such as cavity size, entrance characteristics, and potential threats. The criteria for determining suitability remain largely unexplored. Some colonies engage in simultaneous preparation of multiple cavities before making a final decision and some others make the initial reconnaissance but do not move into the cavity;
- **Transport of building material and food:** Workers seal cracks in the chosen cavity using materials like resin, batumen, or mud. They construct an entrance tube, possibly serving as a visual beacon for nestmate workers. Early food pots are built and filled with honey, requiring a growing number of workers to transport cerumen and honey from the mother nest.
- **Progressive establishment and social link:** The mother and daughter colony maintain a social link through workers traveling between the two nests. The duration of this link varies among species, ranging from a few days to several months. Stingless bee colonies display a preference for cavities previously used by other colonies, containing remnants of building material and nest structures.
- **Arrival of the queen:** After initial preparations, an unmated queen, accompanied by additional workers, arrives at the new nest site.
- **Drone arrival:** Males (drones) aggregate outside the newly established nest. They often arrive shortly after swarming initiation, even before the completion of nest structures. Males can be observed near the entrance, awaiting further events.
- **Mating flight:** Males in aggregations do not enter the colony but await the queen's emergence for a mating flight. Although rarely observed, it is assumed that unmated stingless bee queens embark on a single mating flight, utilizing acquired sperm for the entirety of their reproductive life.

IMPACT OF STINGLESS BEE POLLINATION ON CROP YIELD PARAMETERS

Radish: In seed production plots, stingless bee, constituted 2.78% of all honeybee pollinators contributing to significantly higher number of siliquae per plant, seeds per plant, per cent filled seeds, test weight, and yield in open and bee pollinated plots.

Summer Squash: Under field conditions, *T. iridipennis* was one of the major species among 20% of non-*Apis* pollinators contributing significantly higher fruit set, fruit weight, fruit volume,

good seeds per fruit and 100 seed weight when number of bee visits were maximum (8 bee visits/flower).

Ridge gourd: Under field conditions, *T. iridipennis* was one of the major species among 21.10 % of non-Apis pollinators contributing to significantly higher fruit set, fruit weight, fruit volume, good seeds per fruit and 100 seed weight, when number of bee visits were maximum (8 bee visits/flower).

Cucumber: Under field conditions, *T. iridipennis* constituted 3.24 % of all honeybee pollinators, contributing to significantly higher fruit set, fruit weight, fruit volume, good seeds per flower and test weight, when number of bee visits were maximum (10 bee visits per flower) for *A. cerana*, *A. florea* and *T. iridipennis*.

Coriander: *T. iridipennis* constituted 5.25 % of all honeybee pollinators under field conditions contributing to significantly enhanced number of seeds/umbels, seed weight/umbel and seed size when 8 - 10 bees visited the umbel, irrespective of the bee species.

STINGLESS BEE PRODUCTS

Stingless Bee Honey

Stingless bees are a highly eusocial insect, and similar to European honeybees, stingless bees produce and store honey in their hives. However, the amount of honey stored in the hive of a stingless bee is less than that of European honeybees. Honey stored by stingless bees is fivefold less than that of European honeybees, with the average production per colony of stingless bee honey only up to 1 kg, compared to European honeybee honey, which can be up to 5 kg per colony.

Stingless Bee Propolis

Generally, propolis contains resins gathered by honeybees from their botanical sources mixed with saliva and beeswax inside the hive. Some of the roles of propolis are to seal cracks or openings, protect from threats, and most importantly, for breeding and food storage. In addition, stingless bees also produce propolis called geopropolis, but with the addition of soil materials, which results in a less malleable resin compared to European honeybee propolis. Propolis contains more than 150 compounds, which are a mixture of polyphenols, flavonoids, aglycones, phenolics, and ketones. Additionally, flavonoids and phenolic compounds have been reported as having antioxidant properties. Currently, the needs to discover sources of antioxidant agents are

very important, as humans commonly produce free radicals that could lead to cell damage and mutation.

Stingless Bee Pollen

In general, bee pollen is a collection of pollen grains collected by bees from numerous botanical sources, which are mixed with nectar and digestive enzymes. In addition, bee pollen is used as a food source. During harvesting of bee pollen by humans, the destruction of the hive is inevitable for both stingless bees and European honeybees.

PESTS AND DISEASES

Black Soldier Fly, *Hermitia illucens*:

The adult fly was smoky black winged, measuring 15-20 mm long. Wings were held over the back when at rest. The fly was easily recognized by their two translucent spots on first abdominal segment. The fly thrived on decaying organic matter and occasionally found entry into the stingless bee hives through the entrance tube, especially on weak colonies. The adult fly did not feed on the brood, pollen and honey pots but only the larval stage of the pest damages the colonies. The maggots were dull, whitish color, plump, firm and leathery with tiny yellowish black head. The flattened body was composed of a strongly sclerotized head capsule, three thoracic and eight abdominal segments. The pupae were enclosed in a puparium.



Adult of *H. illucens*



Pupae of *H. illucens*
from a damaged hive

Nitidulid Beetle *Aethina* sp.

The beetle was a destructive pest of stingless bee colonies, causing damage to brood cells, pollen and honey pots. The adult beetle was dark brown and about 5 mm in length. Adults were broad, flattened and oval in shape. Antennae clubbed and elytra are shortened. The adults were found on the rear portion of the brood, pollen and honey pots of a hive. The grubs and adults of beetle were observed on the decaying hive materials. They completed their life cycle inside the damaged hives. Female beetles laid irregular masses of whitish eggs in cracks or crevices in a hive. The eggs hatched into white-coloured grubs in 2–3 days that will grow to 10–11mm length in 10–16 days. Grubs had three pairs of legs and dorsal spikes. The pupae were whitish in colour with a length of 5 mm.



Dorsal view of adult of *Aethina* sp.

DISEASES

The fungus was isolated from abandoned hives, pollen pots, honey pots, propolis and also from the dead bees lying inside the hive floor. Two fungal diseases of stingless bee colonies *Paecilomyces variotii* and *Aspergillus niger*.



P.variotii infection in hive



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SPEAKING FLOWERS: A NEW OF GIFTING

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Introduction

The idea of creating new things through creativity has no limit especially in the present context. One of such lightening ideas in the floriculture industry is “speaking flowers”. The speaking flowers are those in which the flower petals are embossed with images, photos or short messages (HAPPY BIRTH DAY, HAPPY MOTHER’S DAY *etc.*) logos, without harming or shortening the life of the flowers. Speaking roses created an idea over a decade ago that would merge the flower and greeting card industries forever.

Importance

- Some a times, It seems exasperating to select a gift for the person who has everything, Customized gifts can be the answer, and in a day when personalization is in such high demand, using a personalized gift to make a lasting impression on that special someone is a great idea. So the creation of speaking flowers is of those ideas.
- Speaking flowers support the cut flower industry through its value addition.
- Speaking flowers is offering a license package to an entrepreneur that gives them the ability to create market and sell a product with imagination and creativity.
- Speaking flowers offer the best opportunity for the entrepreneurs and the young professionals to use their marketing talents.
- The impact of a logo or personalized greeting on a flower petal is beyond belief.

Characteristics of flower

- The best suitable flowers are rose and tulip.

- The flower stalk should be straight and strong enough to hold the weight of the flower.
- The flower should be healthy with clean and soft petals with attractive colour.
- Flowers should be free from blemishes normally in partially opened and bud condition.
- The selected variety should have enhanced vase and shelf life.



Wishing Messages on flower



Embossing Brand names



Photographs on the flowers



Logos on the flowers

Requirements

- A machine is used to print on the flowers is known as flower printer.
- The quality of this flower printer is unsurpassed, and the template maker that comes with it is speedy and reliable. Printing flowers with this system is fast and simple, and hassle free.
- The message, logo or image that is printed on the flower is clear and easy to read.

Cost, Colour and Category

- The cost of speaking flower varies accordingly from single flower to flower bouquets as 100-1000 INR.
- The colours generally preferred are blue, peach, pink, red, yellow, white depending upon the colour of the flower.
- Categories/occasions include birthday, love, anniversary, congratulations, thanks, get well, sympathy and wedding *etc.*

Benefits

- Speaking flower is became a part from the small occasion like birthday to the Oscar.
- The flowers with message creating the unforgettable memories in life.
- Increasing the economy through this novel floral craft.
- Embossing flowers with a company logo creates a way of advertisement. These can be used for sales promotions, door to door marketing.



Opportunities

- The applications for printed flowers in over 100 billion USD worth of markets, then you'll want to grab this opportunity to create flowers that can not only be a unique gift that everyone will love, but also can be used for advertisements, invitations, weddings, corporate promotions and special events.
- The possibilities for printed flowers are endless and create entrepreneurship.
- One can explore their own creativity and imagination in any way for gaining highly effective marketing.

Conclusion

Speaking flowers explored its value as a novel floral craft in the world, now it is the time to us to develop it in our home also, so government has to provide information and support to all, so that we can add economy to the nation through this blooming floral craft.

GENOME-EDITED RICE: BASICS, BENEFITS, AND FUTURE PROSPECTS

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Introduction

Rice, being a staple food for over half of the global population, holds significant importance in ensuring food and nutritional security. With increasing climate challenges, pest pressures, and the growing need for sustainable agriculture, traditional breeding methods are often too slow to meet these demands. Genome editing, particularly through tools like CRISPR-Cas9, has emerged as a transformative solution, enabling precise, efficient, and targeted improvements in crops like rice.

What is Genome Editing?

Genome editing refers to the use of molecular tools to make specific changes in the DNA of an organism. In agriculture, this technology allows scientists to enhance desirable traits in crops such as drought resistance, disease tolerance, or higher nutritional content but without introducing foreign genes as done in genetically modified crops.

Genome-Edited Rice vs. GM Rice: Key Differences

Attribute	Genome-Edited Rice	Genetically Modified (GM) Rice
Gene Source	Edits the plant's own genes (no foreign DNA)	Introduces genes from other species (transgenic)
Precision	Highly precise; targets specific gene sites	Less precise; can have unintended gene insertions

Regulatory Treatment	Often exempt from strict GMO regulations in many countries	Subject to strict GMO regulatory frameworks
Consumer Perception	Generally more acceptable due to lack of foreign genes	Often faces resistance and skepticism
Development Time	Faster due to simpler regulatory processes	Longer due to extensive testing and approval requirements

Advantages of Genome-Edited Rice

1. **Climate Resilience:** Varieties are being developed to withstand drought, submergence, and salinity—key stressors under climate change.
2. **Higher Yield and Reduced Input:** Genome editing can improve nutrient-use efficiency, reducing the need for fertilizers and water.
3. **Pest and Disease Resistance:** Resistance to bacterial blight and blast disease has been successfully incorporated in several rice lines.
4. **Enhanced Nutrition:** Traits like higher protein content and improved micronutrient levels (e.g., zinc and iron) are being targeted.
5. **Precision and Speed:** Compared to conventional breeding, genome editing is faster, more accurate, and avoids the introduction of unwanted traits.

Recent Developments in India

India has made significant progress in genome-edited rice research. The Indian Agricultural Research Institute (IARI) and other institutes have developed several genome-edited rice lines, including those with, early maturity, reduced arsenic accumulation and improved stress tolerance.

The Department of Biotechnology (DBT) and ICAR are actively promoting genome editing under national agricultural missions. Importantly, India's regulatory framework now distinguishes genome-edited crops (without foreign DNA) from GMOs, paving the way for faster approvals and field-level adoption.

Challenges and Considerations

- **Awareness and Acceptance:** Farmers and consumers need clear communication about the safety and benefits of genome-edited rice.



- **Policy Support:** While regulatory clarity has improved, large-scale adoption requires integration with seed systems and extension services.
- **Ethical and Social Dimensions:** Transparency, trust, and farmer involvement are crucial for successful dissemination.

Taking Genome-Edited Rice to the Fields

Popularising genome-edited rice involves a farmer-focused, multi-pronged approach rooted in communication, education, and trust. Farmer-centric awareness campaigns such as village-level demonstrations, showcasing early maturity, yield improvement, or disease resistance, can build credibility. Sharing real-life success stories through videos and posters in local languages, and leveraging platforms like kisan melas and agri exhibitions, makes the innovation more relatable. Digital outreach through WhatsApp videos, mobile apps, voice notes, and community radio, especially in local dialects, helps explain how genome-edited rice differs from GM varieties. Strengthening training and capacity-building programs for extension workers, Krishi Vigyan Kendras (KVKs), and progressive farmers creates a peer-learning ecosystem. Engaging village leaders and respected local influencers builds social proof and encourages wider adoption. Effective outreach also requires simple, clear messaging like “No foreign gene—just smarter seed” or “Less water, more yield,” while addressing misconceptions gently.

Reaching the youth through school and college activities—including demo plots and nutri-gardens—helps build awareness among the next generation of farmers. Meanwhile, media engagement through regional newspapers, television, and policymaker briefings can accelerate mainstream acceptance. Finally, linking genome-edited rice to social goals like climate resilience, nutritional security, and reduced women’s drudgery enhances its public value and support. Together, these efforts can help bridge the gap from innovation to implementation—taking genome-edited rice from research labs to real fields.

Conclusion

Genome-edited rice represents a groundbreaking leap toward building a resilient, sustainable, and nutrition-secure future. Unlike traditional methods or transgenic modifications, genome editing offers a precise, efficient, and ethically acceptable path to crop improvement—tailored to the urgent needs of farmers facing climate volatility, resource limitations, and market demands.

As India and other developing nations navigate the crossroads of food security and technological innovation, genome-edited rice can serve as a game-changer—empowering farmers, enhancing productivity, and minimizing environmental footprints. However, the true potential of this innovation will be realized only when it is matched with inclusive policies, transparent communication, farmer-friendly extension services, and public trust.

With science in our hands and sustainability in our hearts, genome-edited rice is not just a crop of the future—it is a seed of hope sown today for generations to come.

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WATERMELON: THE ULTIMATE SUMMER SUPERFRUIT

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Introduction

Summer is often synonymous with heatwaves, outdoor adventures, and a heightened need for hydration. In this setting, watermelon (*Citrullus lanatus*) emerges as a quintessential fruit that not only satisfies the palate but also offers essential cooling benefits. With a water content nearing 92–93%, watermelon becomes a natural coolant, perfect for combating summer dehydration. Originating from Africa's Kalahari Desert and adapted to various climates worldwide, it has become a seasonal favorite in homes, markets, and cuisines. In addition to its thirst-quenching qualities, watermelon is loaded with vitamins, minerals, and antioxidants, including lycopene and citrulline, both known for supporting cardiovascular health. Whether consumed as fresh slices, blended into smoothies, or added to salads, watermelon remains a versatile and health-promoting fruit of the summer season.

The Nutritional Powerhouse

Watermelon's composition is deceptively simple, yet it harbors a dense spectrum of micronutrients essential for overall wellness. It provides significant amounts of vitamins A and C, both known for their immune-boosting and skin-protective functions. It also offers B-complex vitamins such as thiamine and niacin that support energy metabolism and nervous system regulation. On the mineral side, watermelon contributes potassium, magnesium, and small amounts of calcium, each playing crucial roles in muscle function, electrolyte balance, and bone health. Importantly, watermelon is naturally fat-free, low in calories (only about 30 kcal/100g), and contains beneficial dietary fiber. These features make it an ideal fruit for weight watchers

and athletes seeking replenishment without the calorie load. It's clear that watermelon stands as more than a seasonal refreshment it's a nutritional powerhouse packed with health-supporting elements.

Bioactive Compounds

Watermelon is particularly rich in **lycopene**, a carotenoid that gives the fruit its red hue and acts as a strong antioxidant. Numerous studies suggest that lycopene may reduce the risk of cardiovascular disease and certain cancers by neutralizing free radicals. Another notable compound is **citrulline**, a non-essential amino acid that supports nitric oxide production and improves vasodilation, which in turn aids in lowering blood pressure. These compounds work synergistically to support vascular and metabolic health, especially under high thermal stress. Watermelon also contains **cucurbitacin E**, a triterpenoid known for its anti-inflammatory and potential anticancer properties. These bioactive agents elevate watermelon's status from a sweet treat to a functional food with tangible health benefits. This biochemical richness makes it particularly suitable for health-conscious individuals and those managing chronic conditions like hypertension.

Health Benefits of Watermelon in Summer

Watermelon's health benefits extend well beyond hydration, offering a full range of physiological advantages that are especially beneficial during summer. Its refreshing nature makes it an ideal fruit for hot days, but its internal chemistry offers support for multiple organ systems.

Table 2. Summarizing the main health benefits of watermelon

Health Benefit	Contributing Nutrients/Compounds	Impact
Hydration	High water content	Replenishes fluids, prevents dehydration
Cardiovascular Health	Potassium, magnesium, lycopene, citrulline	Lowers blood pressure, reduces LDL oxidation
Antioxidant Activity	Lycopene, cucurbitacin E	Neutralizes free radicals, reduces cancer risk
Weight Management	Natural sugars, fiber	Enhances satiety, supports digestion
Anti-Cancer Potential	Lycopene	Decreases risk of certain cancers
Digestive Health	Dietary fiber	Promotes regular bowel movement, improves digestion

Its natural antioxidants, fiber, and amino acids serve as allies for cardiovascular, digestive, and metabolic health. In tropical climates where heat stress is common, incorporating watermelon into the daily diet can significantly reduce dehydration-related complications. The fruit's wide appeal also makes it easy to consume regularly, in contrast to some health foods that may lack palatability. With every juicy bite, watermelon delivers both pleasure and science-backed wellness.

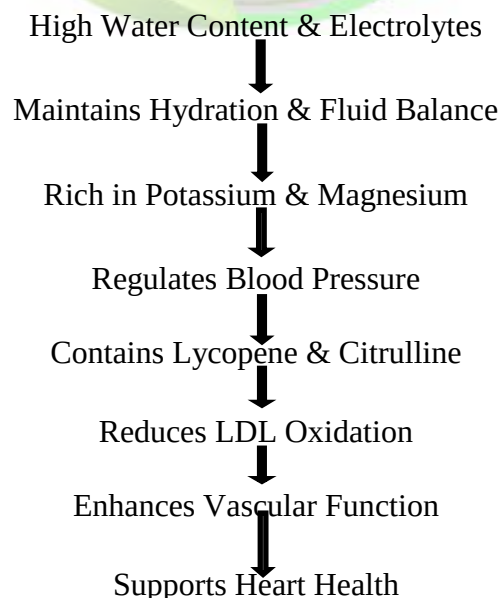
Hydration and Fluid Balance

Maintaining adequate hydration is vital during summer, and watermelon is among the most effective natural sources to do so. With water making up over 90% of its content, it acts like an edible electrolyte drink, replenishing lost fluids due to perspiration. Along with water, watermelon offers potassium a key electrolyte that helps maintain fluid balance and prevents muscle cramps. This makes it particularly beneficial for children, athletes, and the elderly, who are more susceptible to dehydration. Its sweet flavor also encourages higher consumption compared to plain water, making it a more appealing option for hydration. Additionally, the presence of natural sugars in watermelon helps replenish glycogen levels post-physical exertion. This combined profile positions watermelon as both a hydrating and energizing summer staple.

Cardiovascular Health

Cardiovascular benefits are among the most thoroughly researched effects of watermelon consumption.

Fig.1 How Watermelon Supports Heart Health



Lycopene helps reduce the oxidation of LDL (bad) cholesterol, a major risk factor for atherosclerosis and coronary artery disease. Citrulline, another key compound, gets converted into arginine in the body, which supports the production of nitric oxide a molecule that relaxes blood vessels and improves blood flow. Potassium and magnesium further assist in lowering blood pressure and regulating heart rhythm. In one study by Meghwar *et al.* (2024) diets high in lycopene-rich fruits like watermelon were associated with a lower incidence of heart attacks and strokes. These findings are particularly relevant during the summer when heat-induced vasodilation can stress the cardiovascular system. Consuming watermelon regularly may offer a natural strategy to maintain heart health without pharmacological intervention.

Antioxidant and Anti-inflammatory Properties

Oxidative stress is elevated during **summer** due to prolonged exposure to UV rays and heat, but watermelon provides natural defense mechanisms. The lycopene in watermelon has been shown to suppress oxidative damage to cells and DNA, thereby reducing the risk of chronic diseases including cancer and neurodegenerative disorders. Additionally, cucurbitacin E contributes anti-inflammatory effects that help reduce the risk of conditions such as arthritis and inflammatory bowel disease. These antioxidant mechanisms are critical for cellular repair and immune modulation during periods of heat exposure. Watermelon's antioxidants also play a role in preventing photoaging, thereby supporting skin health under sun exposure. Regular consumption can thus serve both cosmetic and systemic protective functions. It's more than a cooling food it's a shield against environmental stressors.

Weight Management and Satiety

Watermelon is ideal for those trying to maintain or reduce weight, especially during summer when appetite patterns shift. Its high-water content gives a feeling of fullness without adding calories, helping reduce overall food intake. Additionally, watermelon's fiber content supports digestion and encourages regular bowel movements, which is crucial for metabolic health. Studies indicate that low-energy-density foods like watermelon increase satiety, reducing the likelihood of consuming high-calorie snacks. This makes it a useful tool in intermittent fasting and other dietary strategies aimed at weight control. The natural sugars in watermelon also provide an energy boost, making it a healthier substitute for sugary snacks and sodas. Consuming watermelon as part of a meal or as a standalone snack supports long-term weight and digestive health.

Anti-Cancer Potential

Numerous studies have evaluated the chemoprotective properties of lycopene, particularly in preventing prostate and breast cancers. Lycopene works by inhibiting the proliferation of cancer cells, modulating inflammation, and preventing DNA damage caused by free radicals. Citrulline and cucurbitacin E may also inhibit pathways associated with tumor development. While more clinical trials are needed, preliminary evidence is promising. Watermelon thus becomes a strategic dietary inclusion for individuals with a family history of cancer or those seeking preventive health. Moreover, its palatability ensures consistent intake, which is critical for realizing long-term chemoprotective benefits. When paired with other antioxidant-rich foods, watermelon contributes to a cancer-resistant dietary pattern.

Digestive Health

Digestive wellness is often disrupted during summer due to dehydration and irregular eating. Watermelon addresses both by combining fiber with ample hydration. This combination ensures smooth bowel function, reducing constipation and bloating. The fruit's fiber also acts as a prebiotic, feeding beneficial gut bacteria and improving microbiome diversity. Additionally, its mild, non-acidic nature makes it suitable for people with sensitive stomachs or those recovering from illness. Research by **Maoto *et al.* (2019)** highlights the potential of watermelon rind in improving digestive function when incorporated into baked goods. Watermelon thus becomes an accessible, natural remedy for digestive irregularities during the hotter months.

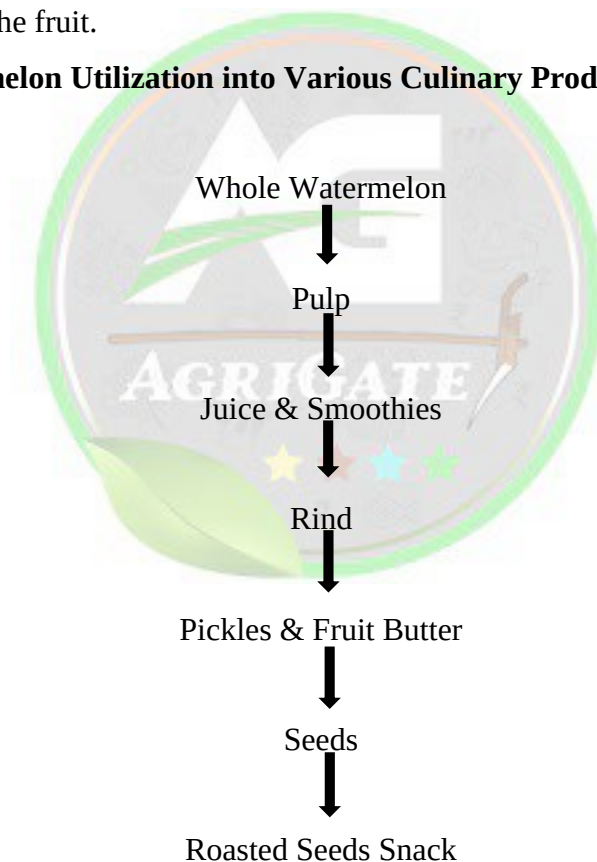
Safety: Addressing Pesticide and Food Safety Concerns

With rising awareness about food safety, concerns have emerged about pesticide residues in fruits. A comprehensive study from Thailand found that while trace levels of five pesticides were detected in watermelon, all were significantly below the Maximum Residue Limits (MRLs) set by international food safety agencies Kataria & Kaur, (2023). These findings are reassuring and suggest that watermelon remains safe for regular consumption. Furthermore, proper agricultural practices, such as controlled spraying schedules and pre-harvest intervals, minimize contamination. Importantly, washing the rind thoroughly before cutting can further reduce exposure risk. Consumers are also advised to choose certified organic or locally sourced melons when available. Safety should not be a barrier to enjoying this nutrient-rich fruit.

Innovative Ways to Enjoy Watermelon

Modern culinary creativity has unlocked many uses for watermelon that extend far beyond fresh slices. The pulp can be juiced, blended, or frozen into popsicles, offering refreshing and healthy alternatives to sugary summer drinks. Smoothies combining watermelon with banana, mint, or coconut water are increasingly popular among fitness enthusiasts. In addition, the **rind**, which is often discarded, has culinary potential. It can be pickled, stir-fried, or even turned into a fiber-rich fruit butter. Research shows that baked products using up to 30% watermelon rind maintain flavor and texture, adding both sustainability and nutrition (Souza *et al.*, 2022). Roasted watermelon seeds are another hidden gem rich in protein and minerals; they are excellent for snacking. These innovations not only minimize waste but also maximize the utility of every part of the fruit.

Fig 3. Flow of Watermelon Utilization into Various Culinary Products



Conclusion

Watermelon is not merely a sweet, cooling fruit it is a **functional food** with significant scientific backing for its health benefits. From hydration to heart health, from weight management to cancer prevention, it serves multiple roles in supporting summer wellness. Despite minor concerns around pesticide residues, research confirms that when grown and



handled responsibly, watermelon is safe and highly beneficial. Innovative uses of the rind and seeds further increase its sustainability and nutritional reach. In a world searching for health-conscious, eco-friendly foods, watermelon stands out as an all-star. Whether you're a dietitian, chef, athlete, or just someone looking for better nutrition, watermelon is a summer gift worth embracing.

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SILENT INVADERS: THE RISING MENACE OF INVASIVE PESTS IN INDIAN AGRICULTURE

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Abstract

India's diverse agro-climatic zones and rich biodiversity make it both agriculturally productive and highly vulnerable to invasive insect pests. In recent years, the frequency and intensity of pest invasions have increased due to global trade, climate change, and weak quarantine enforcement. Pests like the Fall Armyworm (*Spodoptera frugiperda*), Cotton Mealybug (*Phenacoccus solenopsis*), and Tomato Leafminer (*Tuta absoluta*) have rapidly spread across major crop systems, causing severe yield losses and threatening national food security. This article highlights the pathways of invasion, major invasive species affecting Indian agriculture, and the ecological and economic consequences of these pests. It further discusses recent advances in surveillance, early detection, and integrated pest management (IPM) strategies, emphasizing the urgent need for stronger biosecurity policies and farmer awareness to contain and manage future invasions.

Keywords

Invasive insect pests, Indian agriculture, Fall Armyworm, *Tuta absoluta*, Cotton mealybug, Pest outbreaks, Biosecurity, Quarantine, Crop protection, Pest surveillance, Climate change, Integrated Pest Management (IPM), Yield loss, Exotic pests, Early detection, Pest risk analysis, Natural enemies, Biological control, Sustainable agriculture.

Introduction

Agriculture is the backbone of the Indian economy, providing livelihood to more than half of the country's population. However, this vital sector is increasingly threatened by the incursion of invasive insect pests—species that are not native to a particular ecosystem and whose introduction causes or is likely to cause harm. These pests have emerged as a silent yet devastating threat to agricultural sustainability, crop productivity, and food security in India. The past decade has witnessed a dramatic surge in pest invasions, driven by multiple factors such as globalization, climate change, intensive monocropping, and weakened quarantine systems.

The economic toll of invasive pests is immense—not only in terms of direct crop loss but also through increased pesticide use, environmental degradation, and social stress on smallholder farmers. Despite the availability of Integrated Pest Management (IPM) tools, many regions remain unprepared to detect, respond to, or recover from such biological invasions. This article aims to provide a comprehensive overview of the emerging invasive insect pests in Indian agriculture, their pathways of introduction, impacts, and the strategies being adopted to manage them. The discussion further underscores the urgent need for policy reforms, enhanced surveillance, farmer awareness, and research innovation to safeguard Indian agriculture from this escalating entomological threat.

Table 1: Major Invasive Insect Pests in Indian Agriculture

No	Common Name	Scientific Name	Host Crop(s)	Year of Introduction	Native Region
1	Fall Armyworm	<i>Spodoptera frugiperda</i>	Maize, Sorghum, Sugarcane	2018 (Karnataka)	Americas
2	Tomato Leafminer	<i>Tuta absoluta</i>	Tomato, Brinjal, Potato	2014 (Maharashtra)	South America
3	Cotton Mealybug	<i>Phenacoccus solenopsis</i>	Cotton, Okra, Sunflower	~2006 (Punjab)	Central America
4	Papaya Mealybug	<i>Paracoccus marginatus</i>	Papaya, Hibiscus, Tapioca	2008 (Tamil Nadu)	Mexico/Central America
5	Spiralling	<i>Aleurodicus</i>	Coconut, Guava,	1990s (Kerala)	Caribbean/Ce



	Whitefly	<i>dispersus</i>	Banana		Central America
6	Rugose Spiraling Whitefly	<i>Aleurodicus rugioperculatus</i>	Coconut, Banana, Arecanut	2016 (Kerala)	Central America
7	American Serpentine Leafminer	<i>Liriomyza trifolii</i>	Tomato, Beans, Cucumber	1990s	North America
8	Cassava Mealybug	<i>Phenacoccus manihoti</i>	Cassava, Tapioca	2022 (Tamil Nadu)	South America
9	Coconut Eriophyid Mite	<i>Aceria guerreronis</i>	Coconut	1998 (Kerala)	Central America
10	Red Palm Weevil	<i>Rhynchophorus ferrugineus</i>	Coconut, Date palm	~1990s (Tamil Nadu)	Southeast Asia
11	Banana Skipper	<i>Erionota thrax</i>	Banana	2015 (Northeast India)	Southeast Asia
12	Coffee Berry Borer	<i>Hypothenemus hampei</i>	Coffee	1990s (Karnataka)	Africa
13	Guava Fruit Fly	<i>Bactrocera correcta</i>	Guava, Mango	Early 2000s	Southeast Asia
14	Brinjal Shoot and Fruit Borer (exotic strains)	<i>Leucinodes orbonalis</i>	Brinjal	—	Asia (invasive strains from Southeast Asia)
15	Maize Stem Borer (East African race)	<i>Busseola fusca</i>	Maize	Risk Observed	Sub-Saharan Africa

Source : ICAR-National Bureau of Agricultural Insect Resources (NBAIR). (2021)

Rugose Spiraling Whitefly

Fall Armyworm



Source : <https://www.syngentaseedcare.com>

<https://eruvaaka.com/>

Causes and Pathways of Invasion :

Causes of Invasive Pest Incursions

1. Global Trade Expansion

The liberalization of agricultural trade and increased import-export of plant material, fruits, vegetables, flowers, and timber has significantly elevated the risk of pest invasions. Contaminated shipments can serve as carriers of eggs, larvae, or adult pests.

2. Weak Quarantine and Phytosanitary Measures

Despite the presence of Plant Quarantine (Regulation of Import into India) Order, 2003, implementation at ports of entry is often inadequate due to limited infrastructure, manpower, and surveillance tools.

3. Climate Change

Changing temperature and rainfall patterns can make new regions suitable for exotic pests. Rising temperatures also accelerate pest life cycles and enable their survival in previously hostile areas.

4. Human Movement and Tourism

Travelers often unknowingly carry plant material, soil, or food products that harbor exotic insects or eggs, facilitating unintentional pest introduction.

5. Lack of Public Awareness

Farmers and nurseries may inadvertently introduce pests through uncertified planting materials or infested nursery stock, unaware of biosecurity risks.

Pathway	Examples
Plant Material Imports	Infested seeds, cuttings, saplings from other countries
Commodity Trade	Movement of vegetables, fruits, grains (e.g., papaya, maize)
Contaminated Machinery	Harvesters, containers, or crates carrying pest residues
Natural Dispersal	Wind dispersal or flight from bordering countries
Human Activities	Tourism, smuggling, or ornamental plant trade

Table 2 : Pathways of Pest Invasion

Source : Food and Agriculture Organization (FAO). (2019). *Global Report on Invasive Species*

Management Strategies :

Effectively managing invasive insect pests requires a multi-pronged approach, combining traditional knowledge with modern innovations. Below are the key strategies currently employed and recommended in India:

Integrated Pest Management (IPM)

Biological Control:

- Use of natural enemies like parasitoids, predators, and entomopathogens.
- Example: Release of *Trichogramma* spp. against *Helicoverpa armigera* and *Spodoptera frugiperda*.
- *Beauveria bassiana* and *Metarhizium anisopliae* used as biopesticides.

Trichogramma spp

Bio Pesticide - *Beauveria bassiana*



Source : <https://www.buglogical.com>

Cultural Practices:

- Crop rotation, clean cultivation, removal of infested plant debris, and optimal sowing dates help disrupt pest life cycles.

Mechanical Control:

- Light traps, pheromone traps, and hand-picking of egg masses/larvae.
- Installation of yellow sticky traps for whitefly and leafminer management.

Light Trap



Pheromone Trap



Yellow Sticky Trap



Source : <https://www.khethari.com>

Botanical Insecticides:

- Neem-based formulations (Azadirachtin) have shown efficacy against several soft-bodied pests.

Early Detection and Surveillance Systems

Digital Tools:

- Mobile apps such as *Plantix*, *Kisan Suvidha*, and *Pestoz* enable real-time pest identification and advisory.
- GPS-enabled pest surveillance systems and remote sensing tools are being piloted.

Digital Tools (Mobile Applications)



Source:- <https://plantix.net/> <https://kisansuvidha.in/> <https://pestoz.en.aptoide.com>

Drones and IoT Sensors:

- Emerging use of drones for aerial surveillance and automated pest scouting.
- Internet of Things (IoT) sensors monitor microclimatic conditions that favor pest outbreaks.

Case Studies :

- Fall Armyworm (*Spodoptera frugiperda*) in Karnataka (2018)

The Fall Armyworm (FAW) is one of the most devastating invasive pests to hit Indian maize cultivation. First reported in Karnataka in 2018, it rapidly spread to other states causing crop losses up to 50–70% in affected fields. The pest's high reproductive rate, polyphagous nature, and resistance to multiple insecticides made it a formidable challenge.

- Impact: Significant yield reduction and economic losses estimated at over ₹2000 crore in the first year.
- Management: Initial heavy pesticide use led to resistance; subsequently, IPM strategies incorporating pheromone traps, biopesticides, and parasitoid releases helped contain the outbreak.

Fall Armyworm In Maize



Source : <https://www.rural21.com>

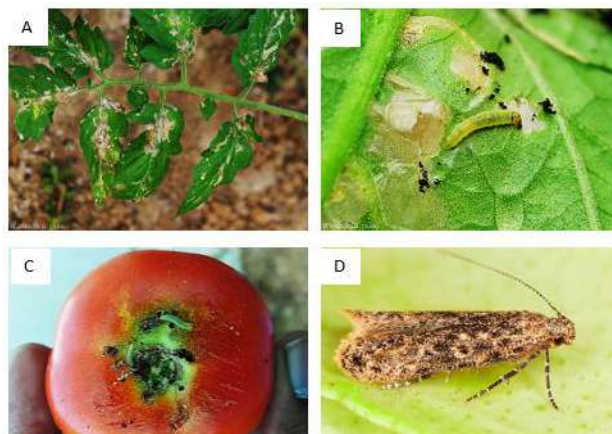
- Tomato Leafminer (*Tuta absoluta*) in Andhra Pradesh

Introduced around 2014, *Tuta absoluta* quickly became a major pest for tomato growers in Andhra Pradesh and Telangana. It causes direct damage by mining leaves, stems, and fruits, resulting in yield losses exceeding 80% without management.

- Impact: Reduced fruit quality and quantity, forcing many farmers to switch crops temporarily.

- Management: Adoption of pheromone traps for early detection, cultural controls such as removing infested plant parts, and biological control agents like *Trichogramma* species were effective. Government advisories helped promote awareness.

Tomato Leaf Miner



Source :- <https://www.syngentaseedcare.com>

➤ Papaya Mealybug (*Paracoccus marginatus*) in Tamil Nadu

First detected in Tamil Nadu in 2008, this mealybug rapidly spread, affecting papaya, hibiscus, and other crops. It excretes honeydew, leading to sooty mold development and weakening plants.

- Impact: Yield losses of up to 40% and increased pesticide dependence.
- Management: Release of parasitoids such as *Acerophagus papayae* and adoption of IPM techniques minimized pesticide use and improved crop health.

Papaya Mealy Bug



Source : <https://iapps2010.wordpress.com>

Challenges and Knowledge Gaps

Despite efforts, managing invasive pests in India faces several challenges:

- Weak Quarantine Enforcement:
Gaps in border inspections and inadequate infrastructure allow pest entry.
- Limited Farmer Awareness:
Many small-scale farmers lack knowledge of invasive pests and IPM practices.
- Resistance Development:
Overreliance on chemical pesticides has accelerated resistance in pests like *Spodoptera frugiperda*.

Conclusion

Invasive pests present a growing threat to India's agricultural productivity, economy, and food security. Their introduction through global trade, climate change, and weak biosecurity highlights the need for vigilant monitoring and integrated management. Strengthening quarantine, empowering farmers, and advancing research are critical to sustainable pest control. Coordinated efforts between government, researchers, and stakeholders will help mitigate impacts and secure India's agricultural future.

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BOOSTING BLACKGRAM PRODUCTIVITY WITH LBG-904 VARIETY: A SUCCESS STORY FROM ANAKAPALLI DISTRICT

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Introduction

Blackgram (*Vigna mungo*), also known as urad, is an essential pulse crop in India, widely grown for its high protein content and soil-enriching properties. In Anakapalli district of Andhra Pradesh, blackgram is cultivated on a large scale—approximately 8,984 hectares during the Rabi season under irrigation and around 228 hectares during the Kharif season under rainfed conditions. Despite its popularity, many farmers struggle with declining productivity due to pest and disease pressures, rising input costs, and lack of access to improved technologies. This article showcases the success story of Mr. Sayam Raghunadh, a farmer from Bangarumetta village, who adopted the LBG-904 blackgram variety and achieved remarkable results during the Rabi 2024 season.

Challenges in Blackgram Cultivation

- Blackgram cultivation is often hindered by several issues, including: YMV, Powdery mildew, Anthracnose leaf spots and Other Sucking pest etc.,
- In addition to these diseases, high costs for seeds, fertilizers, and plant protection chemicals reduce the profitability of blackgram, especially for small and marginal farmers.

Introduction of the LBG-904 Variety

To overcome these constraints and enhance productivity, the Krishi Vigyan Kendra (KVK), Kondempudi, introduced the LBG-904 blackgram variety. This initiative was part of the National Food Security Mission (NFSM), focusing on increasing pulse production through Cluster Front Line Demonstrations (CFLDs) and Integrated Crop Management (ICM) practices.

About the LBG-904 Variety:

The Variety Released from the Regional Agricultural Research Station (RARS), Lam, Guntur in 2023. LBG-904 is a high-yielding, polished blackgram variety with several desirable characteristics:

- Crop duration: 85–90 days
- Resistant to: Powdery mildew and other common diseases
- Adaptability: Suitable for all seasons and well-suited for rice fallow lands
- Yield potential: 8–10 quintals per acre

This variety is gaining popularity among farmers due to its resilience and consistent performance.



Training and Demonstration Activities:

In the second fortnight of November 2024, the KVK Kondempudi organized training programs for farmers on improved blackgram cultivation practices. As part of the CFLD initiative, inputs were distributed to 250 farmers across various villages in Anakapalli district, including:

- LBG-904 seed
- Imidacloprid, Yellow Sticky Traps, Multi-k, Neem oil, Emamectin benzoate and Acephate
- Weedicides for early-stage weed control (Imazethapyr)

I was one of the selected farmers from Bangarumetta village who received these inputs and technical guidance.

Implementation and Outcomes:

I sown the LBG-904 variety on December 6, 2024, and received regular support and field visits from KVK scientists. They guided me on scientific practices such as:

- Seed treatment and spacing
- Timely irrigation and weeding
- Nutrient management
- Integrated pest and disease management

Thanks to the adoption of these ICM practices, I was able to harvest an excellent yield of 5.55 quintals per acre, resulting in a net income of ₹27,980 per acre. This was a significant improvement over previous seasons using traditional varieties.

By implementing scientific management practices, Mr. Raghunadh recorded the following outcome:

- Yield: 5.55 quintals/acre
- Sale Price: ₹70/kg
- Gross Income: ₹38,850/acre
- Net Income: ₹27,980/acre

This was a significant increase in income compared to previous years, when poor management led to low productivity.

Impact and Farmer's Perspective:

Mr. Raghunadh expressed that although he had been growing blackgram for several years, he had never achieved such results before. The adoption of proper crop management



practices based on KVK's guidance directly contributed to higher productivity and profitability. He emphasized that scientifically validated seeds and improved agronomic practices are key to transforming farmer livelihoods. This success story has become a guiding light for many fellow farmers in the region.

Conclusion

The successful cultivation of LBG-904 blackgram has demonstrated the value of improved seed varieties and scientific crop management. This initiative by KVK Kondempudi under the NFSM -CFLD Pulses program has not only enhanced my productivity and income but also created awareness among fellow farmers in my region. The LBG-904 variety shows great promise for large-scale adoption, especially in regions practicing rice fallow cultivation. I sincerely thank the agricultural scientists and extension personnel for their continued support and guidance in making this a success.



SUMMER MANAGEMENT IN ANIMALS

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Introduction

Global food security is greatly influenced by the significant agricultural industry of livestock. Climate change has emerged as a major danger to the livestock industry. Heat stress brought on by climate change has emerged as a major element influencing animal output. Farm animals are considered homoeotherms because they can maintain a relatively steady body temperature within specific bounds even in the face of significant climate change. Animal production suffers when body temperature deviations from the specified level occur in a stressful, hot environment because they interfere with physiological processes.

The animals have a variety of adaptive strategies to deal with the shifting climate. The morphological, anatomical, physiological, biochemical, and behavioural traits of animals that enable them to thrive in a particular environment define their capacity for adaptation. Sweating rate (SR), skin temperature (ST), pulse rate (PR), respiration rate (RR), and rectal temperature (RT) are a few physiological factors that influence responses to heat stress. Based on the THI, a lot of research has been done on determining if dairy animals are thermally comfortable or uncomfortable. Increases in temperature can have a significant impact on livestock's health, productivity, and ability to reproduce.

Because heat stress alters or impairs eating activity, it also impacts metabolic and digestive processes. Ruminal contractions are slowed down by heat stress, which consequently slows down digestion. Animal health, reproductive efficiency, meat production, and milk production and quality can all be negatively impacted by heat stress.

To address these issues, it is necessary to create mitigation strategies that include management techniques, dietary adjustments, elements that sustain health, and animal breeding initiatives that incorporate heat tolerance.

Precautions to manage the Heat stress in animals

1. Provision of clean water

Increasing water availability to the animals is one of the most important strategy to alleviate heat stress. The consumption of water increases sharply as the environmental temperature increases because of greater water losses from rapid respiration and sweating.

2. Dietary management

Fermentation of feedstuffs in the rumen creates heat. This heat of fermentation is not beneficial in a hot season. Reduced DMI associated with heat is almost certainly the body's mechanism of reducing heat of fermentation simply by reducing the amount of feed to be fermented in the rumen. Various dietary approaches or feeding strategies have been used to alleviate the adverse effect of heat stress. They aim to maintain water balance, nutrients and electrolytes intake and/or to satisfy the special needs during heat stress such as vitamins and minerals.

The depressed feed intake in hot weather is commonly considered as an adaptation to reduce metabolic heat production. The most limiting nutrient for cattle during heat stress is usually energy intake. A common approach to minimize the reduction of energy and nutrient intake under heat stress is increase in energy density to reduce forage intake and also increase energy or protein concentrate in the ration to overcome the low DM intake.

a) Decrease Fiber level in the ration

Adequate fiber in the diet is essential to maintain rumen health, and high quality forage helps to maintain feed intake. The heat of fermentation of individual feedstuffs rises with its total fiber (i.e., NDF) content. Thus forages with the highest fiber quality (i.e., the fastest fermenting) should be fed as they have a lower heat of fermentation and higher energy value.

b) Addition of Fat in the ration

Fats are commonly used feed ingredient in rations and they are very high in energy. Increasing the amount of dietary fat has been widely accepted strategy in order to reduce basal metabolic heat production.

Increasing the energy content of the diet via lipid addition can partially overcome the

effect of heat stress. Recently Melo et al. (2016) reported that supplementation of palm oil significantly reduced rectal temperature and respiratory rate, increased milk yield, reduced dry matter intake and increased feed efficiency in lactating cow. Feeding supplemental saturated fatty acids (SFA) during heat stress decreased the body temperature during the hottest time of the day and increased milk yield. Growth performance was improved in heat-stressed finishing pigs fed high-fat diets.

c) Protein supplementation

As DMI is depressed due to heat stress, it is necessary to increase the protein level of the ration. The proportion of the dietary protein that must be provided as rumen un-degraded protein (bypass protein), slow-release nitrogen or bypass amino acids must be increased, since the net passage of microbial protein from the rumen declines with lower DMI.

3. Mineral and Vitamin supplementation

In proportion to the drop in DMI, the mineral densities in the ration ought to be raised. The main osmotic regulator of water secretion from sweat glands in cows is potassium. In buffaloes under heat stress, electrolyte supplementation reduced oxidative stress and enhanced cell-mediated immunity. Because cows perspire more when under heat stress, their feed should have extra sodium.

a) Selenium

Natural and synthetic anti-oxidants in the feed as well as optimal levels of minerals help to maintain efficient level of endogenous anti-oxidants in tissues. Selenium protects tissue against oxidative stress. Increase in immune-competence at parturition, an improvement in uterine health and second pregnancy rate during summer months in cows fed selenium-yeast prior to calving.

b) Chromium

During heat stress, animals gain greatly from increased glucose availability and utilisation. An important micronutrient that enhances the effects of insulin on the metabolism of proteins and glucose is chromium. Increased insulin sensitivity was observed in heifers supplemented with higher levels of chromium, indicating that chromium is crucial for ruminant glucose metabolism. Additionally, by continuously lowering serum cortisol levels under stress, chromium supplements reduce the adverse effects of the stress response. In buffalo calves exposed to the summer, dietary inorganic chromium supplementation enhanced immunological function, heat tolerance, and insulin hormone potency.

c) Niacin

The effects of feed additives, such as vitamins, on the animals' capacity to handle heat stress were examined. Niacin is well known for its impact on lipid metabolism and blood vessel dilation, which increases sweat gland activity in cattle. Under moderate heat load, cows fed rumen-protected niacin exhibited lower vaginal and rectal temperatures. The thermo-tolerance of winter-acclimated nursing dairy cows subjected to moderate heat stress was not improved by supplementing with encapsulated niacin.

4. Rumen Fermentation Modifier

An ionophore called monensin is a well-known rumen fermentation modulator that improves the glucose status of heat-stressed cows by increasing the formation of propionate, the primary glucogenic precursor in ruminants. Live yeast cultures (*Sacchomyces cerevisiae*) have been widely employed to improve ruminant animals' nutritional utilisation.

Housing Management

It is extremely difficult and fraught with increasing difficulties to manage a dairy herd during periods of intense heat. At the level of the husbandry and management system, there are a number of options available, such as structural changes, cooling methods (fans, misters, sprinklers and cooled waterbeds), providing enough shade, and controlling feeding schedules (moving to cooler times in the evening, night and early morning to reduce heat stress in animals).

a) Shade

One of the simplest strategies to reduce heat is to provide shade. Cattle benefit from shade in terms of their physiology, behaviour, and productivity. Although shade shields cows from the sun, it may not have an impact on the humidity or temperature of the surrounding air, which could limit the cows' innate capacity to disperse heat. Trees' natural shade offers varying degrees of protection from the sun and wind.

b) Shelter

Shelter management is one of the key techniques for reducing the impact of heat stress in livestock. A good shelter should protect the animals from extreme climatic condition without compromising the animal performance in terms of growth, health and reproduction.

c) Orientation

A shed that is orientated with its long axis running east-west is cooler than one that is orientated north-south. The shelter's floor is colder since it is shaded for a larger portion of the

day. As a result, this orientation encourages heat escape from the animal's body to the surroundings through conduction and radiation.

d) Shelter design and height of shelter

Compared to closed shelters, open sheds have advantages. To lessen heat load, the minimum roof height should be ten feet. A height below 3.0 meters hinders adequate ventilation, which lowers the amount of heat that animals lose through convection.

e) Shape and Roof type

The shape of the roof can be either flat, slopped or “A” shaped. “A” shaped roof is definitely better than a flat roof in hot climate.

f) Roof material

The roofing material may be straw or hay, plywood, galvanised steel, and other polymers. Hot, dry climates are better suited for hay thatch than hot, humid ones. Wood is a fantastic material for sheds, but it breaks easily and requires periodic treatments. In a double roof shelter, asbestos sheets work better as the top layer. Reflective roofs, such white galvanised or aluminium roofs, are the best in lowering heat load.

g) Color of Roof and Wall

It should be white outside and coloured inside. Painting of side walls white from outside reduces the surface temperature of the walls inside by 12 to 22°C in comparison to unpainted walls at air temperature above 37°C.

h) Cooling system

In addition to offering shade, it was discovered that using water as a cooling agent was an effective way to lessen the effects of heat stress on animals, especially in arid, hot settings with lower humidity levels. The two methods of evaporative cooling in animals are direct evaporation from the animal's skin surface and indirect evaporation, which involves cooling the animal's microenvironment in an enclosed shed using fans and cooling pads.

During periods of extreme heat, water can be sprayed on the shelter's roof and floor either intermittently or continuously to lower their temperature and, as a result, lessen the heat burden. The air flowing through the grass screens on the sides of the shelter is significantly cooled when there is water present. Adequate cross ventilation is necessary. In the summer, we can artificially lower the heat burden on animals by repeatedly misting them with a tiny amount of water every

15 to 30 minutes. Water evaporation is accelerated in cow sheds by the installation of fans or blowers.

There are numerous direct cooling techniques, such as sprinkling systems, fogging, and misting. Sprinkling employs huge water droplets to directly moisten the animal's hair coat rather than trying to chill the air like fogging and misting do. Sprinkling, on the other hand, lowers the ambient air temperature near the animals, increasing the effectiveness of the non-evaporative cooling mechanism.

5. Health Management

Maintaining animal health is an important aspect if one attempts to sustain livestock production during heat stress condition. Efforts are need to be taken to maintain normal animal health during stressful condition. Developing public awareness and other health education programmes to tackle different diseases that arise as a result of heat stress are the primary requirement to tackle health issues.

6. Genetic and Breeding Management

Understanding the mechanisms of thermoregulation and identifying the genes that give certain livestock species their superior thermo-tolerant capability depend heavily on genomic and proteomic research. Developing a livestock breed with a high degree of thermotolerance can be accomplished with the use of breeding technology advancements. To create a breed that is appropriate for various agro-ecological zones, breeds that can withstand environmental stressors without sacrificing their ability to produce must be found and put through breeding processes. The evolution of heat-resistant breeds is achieved through genetic improvement.

Conclusion

Severe heat stress in dairy animals is seen as a result of rising average temperatures and humidity, which causes health issues and output losses. Animal health, nutritional therapies, physical environment modification, and genetically thermotolerant animals are some of the strategies used to treat heat stress in animals. Heat stress causes a decrease in dry matter intake but an increase in energy requirements. To reduce heat stress in dairy animals, dietary solutions include raising water availability, energy and nutrient densities, and offering specialised supplements. From a managerial standpoint, environmental alteration includes the construction of sheds, cooling systems (fans and mist), and shade.

MASTITIS IN COWS – A FIELD POINT OF VIEW

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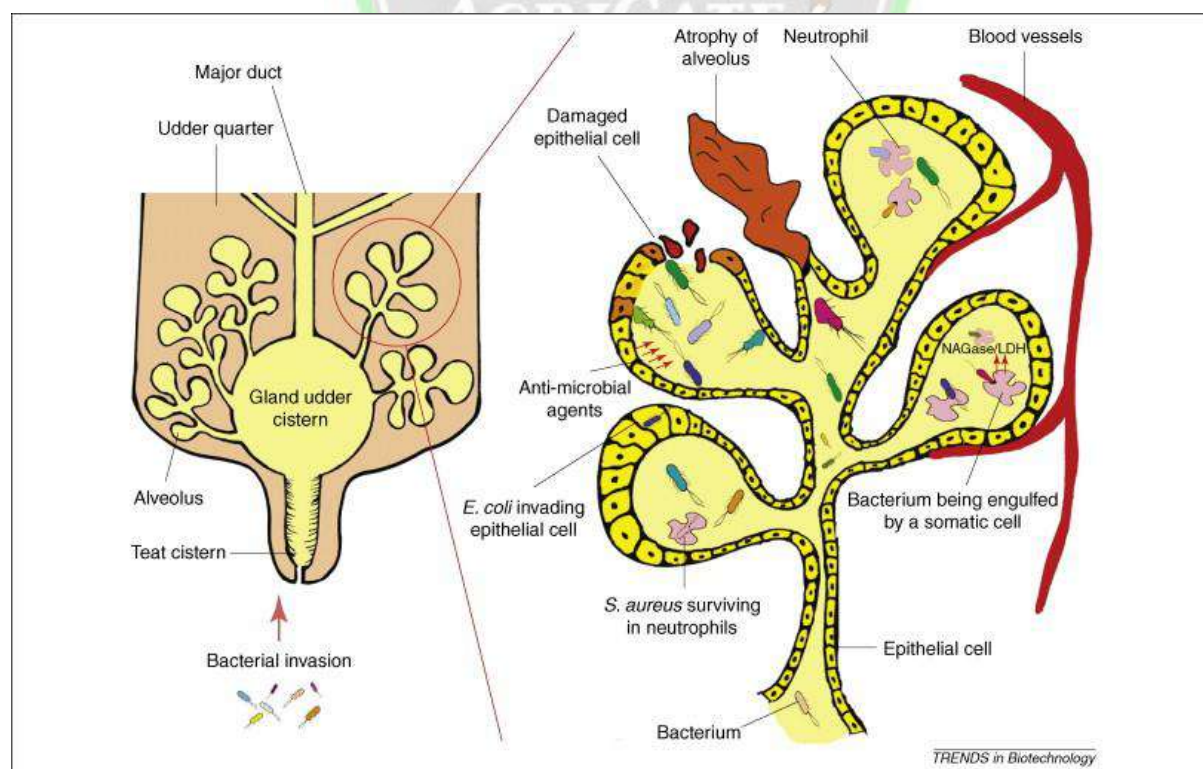
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Introduction

Mastitis is inflammation of the parenchyma of the mammary gland regardless of the cause. Mastitis is therefore characterized by a range of physical and chemical changes in the milk and pathological changes in the glandular tissue. The most important changes in the milk include discoloration, the presence of clots and the presence of large numbers of leukocytes. There is swelling, heat, pain and oedema in the mammary gland in many clinical cases. Mastitis leading to high economic losses in the dairy industry.



This inflammatory disease has been known to cause a significant reduction in productivity, affecting both the quality and quantity of milk and also causing culling of animals at an unacceptable age. Mastitis is one of the most prevalent and costly diseases of cows. It occurs when microbes enter the teat via the teat canal follows inflammatory reaction by releasing the toxin in the teat canal and mammary tissue. The severity and duration of mastitis are critically related to the promptness of the neutrophil migratory response and their bactericidal activity at the site of infection.

Etiology:

Bacterial causes, are more and even among that worldwide. staphylococcus, streptococcus, E-coli, and mycoplasma Mastitis are the common ones.

Contagious pathogens:

Staphylococcus aureus - *S. aureus* is one of the significant pathogens causing mastitis in dairy ruminants in many countries especially post calving. Streptococcus agalactiae, Mycoplasma bovis and Corynebacterium bovis.

Teat skin opportunistic pathogens:

Coagulase-negative staphylococci - was classified as minor pathogens and their importance as an independent cause of subclinical or clinical mastitis was judged to be limited. However, the significance of CNS needs to be reconsidered as in many countries they have become the most common mastitis causing agents. In India, the prevalence of CNS in milk samples increased from 9.91% in 2003 to 72.13% in 2009.

Environmental pathogens: environmental Streptococcus spp. including Streptococcus uberis and Streptococcus dysgalactiae, which are the most prevalent; less prevalent is Streptococcus equinus (formerly referred to as Streptococcus bovis) .

Environmental coliforms include the Gram-negative bacteria Escherichia coli, Klebsiella spp. and Enterobacter spp.,

Trueperella (formerly Arcanobacterium) pyogenes is common in dry cows and heifers that are pastured during the summer months on fields and that have access to ponds or wet areas.

Uncommon pathogens:

Nocardia spp., Pasteurella spp., Mycobacterium bovis, Bacillus cereus, Pseudomonas spp., Serratia marcescens, Citrobacter spp., anaerobic bacterial species, fungi and yeasts

Virus causes, virus either directly or indirectly they cause Mastitis. The causatives can be Herpes viral mammilitis or in cases of FMD or in cases of LSD.

The Fungal causes are Candida species, Aspergillosis, Trichophyton, and Penicillium can also cause mastitis. Generally, it is uncommon or rare. But a low prevalence of fungal mastitis of 2 to 7% has been reported. The prevalence of mycotic mastitis is usually very low (1-12% of all mastitis causes) but sometimes it can occur in enzootic proportions.

Clinical signs:

Gross abnormalities in milk - Discoloration, clots, flakes, pus.

Physical abnormalities of udder: acute - diffuse swelling, warmth, pain, gangrene in severe cases

Chronic - local fibrosis and atrophy

Systemic response: may be normal or mild, moderate, acute, peracute with varying degrees of anorexia, toxemia, dehydration, fever, tachycardia, ruminal stasis, and recumbency and death.

Three categories of Clinical Mastitis

Abnormal Secretion, Abnormal Quarter and Abnormal Cow.

In Abnormal secretion, we may find flakes or watery milk or even blood tinge in the milk but there won't be any change in the udder or in the animal.

In Abnormal udder, There may be Inflammation of the udder, that is swollen or rigorous. There may be pain on palpation and There may be local or diffused fibrosis.

In an abnormal cow, the animal will show signs of Anorexia, toxemia, there may be pyrexia, there may be inheritance and even there may be recumbency.

Sub-clinical Mastitis can be defined as inflammation of the udder in the absence of any physical changes in the milk and also in the udder. Subclinical mastitis is mostly asymptomatic and represents infection without apparent signs of local inflammation, It will not be usually visualized by the farmer. In some cases, he may report only the reduction in milk yield. Commonly caused by *S. aureus* and *Streptococcus sp.* Subclinical mastitis can only be detected by laboratory examination and

Chronic Mastitis, the udder may be regressed, feeling empty, and there may be scanty secretion or even no secretion and on careful palpation, you will be able to feel the fibrosis.

In clinical examination; we have to examine all the quarters and the teat for similarity or any inflammation or fibrosis and we have to check the secretion for any changes and we have to

check for the confirmation of the test, whether there are any deviation or convergence are to be considered.

Dry Cow

Involution of the mammary parenchyma begins 1–2 days after the end of lactation and continues for 10–14 days. During this time, the gland is particularly vulnerable to new IMI.

Diagnosis:

Field tests:

1. PH test:

Normally the *pH* of milk should be within the range of 6.3 to 6.7, so if the pH is more than 6.7 or less than 6, it can be considered Mastitis even without any changes in the milk.

2. CMT:

CMT is considered the cheapest and best reliable field site test, wherein the principle is that the CMT reagent will lie in the cell and interact with the DNA which coagulates to form gel formation suitable for subclinical mastitis. So here we have to take 5 ml of milk with an equal quantity of the reagent and we have to stir it with this toothpick and the result should be read within 20 to 30 seconds.

3. STRIP CUP TEST:

In this test we have to use a black cup which will show the presence of any clots or any other change in the milk well.

4. WHITE SIDE TEST:

White side test is mix 2 ml of 4% NaOH with 10ml of milk formation of viscid mass indicating mastitis milk.

5. RAPID CATALYST TEST:

It is an old method of testing, we have to take two or three drops of milk on a glass slide and add an equal quantity of 9% Hydrogen Peroxide and within one minute, you can see the bubble formation which indicates a positive case.

6. SOMATIC CELL COUNT:

Somatic cell count (Leucocyte count) is another field site test that can be done for individual animals or even for bulk tank milk, so

- if the reading is less than 1 lakh it is taken as normal
- if the reading is more than 2 lakhs it is considered the presence of Mastitis and

- if the reading is more than 3 lakhs it requires examination of that individual animal

Treatment

1.Fluid therapy

Isotonic saline is administered, 30–40 L are necessary throughout a 4-hour period, which can be difficult under farm conditions. A practical alternative is 2 to 4 L of 7% NaCl (hypersaline) administered IV. This induces rapid fluid uptake from the body compartment into the circulation. Cows should then be offered free-choice water to drink, and if at least 8 to 10 gallons is not consumed, 5–7 gallons should be pumped into the rumen. This technique is very useful in case of endotoxemia caused by coliform mastitis. Cows with endotoxic shock are marginally hypocalcemic; thus, 500 mL of calcium borogluconate should be administered SC (to avoid potential complications of IV administration). Alternatively, rapid absorption calcium gels, designed for periparturient hypocalcemia, can be given. If the cow remains in shock, continued fluid therapy should be administered PO or IV as isotonic, not hypertonic, fluids.

2.Oxytocin

The usage of Oxytocin, at the dose of 10 to 20 IU Intramuscular, can help in flushing out the pathogens and also it helps in the migration of the neutrophils.

3. Anti-inflammatory

Ketoprofen 3.3 mg/kg I/M per day (Crosses milk blood barrier)

Flunixin meglumine 1.1mg/kg I/V per day (Immediate supportive treatment of endotoxic shock caused by coliforms)

Dexamethasone 30mg/kg I/M per day

All above medicine should be given minimum of 3-5days

3. Antibiotics

Lipophilic antimicrobial drugs that distribute well into mammary tissue, such as oxytetracycline (11 mg/kg/day), are the best candidates for systemic administration, although several studies have found oxytetracycline (administered for 4 days or less) to be ineffective.

Ceftiofur sodium 2.2 mg /kg IM (act against gram negative organism)

Gentamicin 4 mg /kg I/V (coliform mastitis)

Ceftizoxime (M Ceft) 5 to 10mg /kg /day/ I/V (long withdrawal period – 7 days in milk)

Marbofloxacin (Marbomet) @ 4-8mg /kg/BW most of the gram negative organism and mycoplasma

Previous experience is important to choose the suitable antibiotics.

4. Intra Mammary Therapy

Commercial intramammary products that contain amoxicillin, penicillin, or cephalosporins are recommended one and **multiple-dose vials (labelled for systemic therapy) should *not* be used for intramammary therapy.**

Intramammary infusions of beta-lactam antibacterial drugs 7–14 days before expected calving dates have been reported to reduce the prevalence of Intra Mammary Infection at calving.

In subclinical mastitis commercial Intra Mammary Therapy contains prednisolone for 10 days will be a useful one.

Alternative medicine:

Herbal therapy of Mastitis

- Mixture of 200 g Aloe vera (200g), turmeric powder (50g) and lime (5g) paste (external) was found to be suitable to treat all type of mastitis without any adverse effects.
- Use of 50 g turmeric powder, 20-25 g limetone, 250 g Aloe vera and lemon juice of two fresh lemon, mix it thoroughly to make a paste 150-200 ml of water and apply externally over the affected part of udder. Repeat 10 times a day up to 5 days.
- Feeding of 20-30 gm camphor in banana fruit twice in day up to three days is also very effective in milk with blood or abscess condition.
- Hot fomentation of udder by using neem leaves boiled in hot water with magsulf and boric acid and apply over teat thrice in a day.
- In mild teat infection, freshly plucked & clean leaf stalk of neem leaves and making the paste of turmeric powder with butter or ghee and coat this paste over affected teat.
- Use of palm oil, medium chain fatty acids for treatment of mastitis, having the antibacterial properties.

Homeopathy

Oral use

Combination of Phytolacca, Silicea, Belladonna, Bryonia, Ipecac Calc. Fluor, Arnica, and Conium are used in all kinds of Mastitis as liquid 15 drops BID (all 200c potency)

Intramammary use

The combination of Belladonna, Calendula, Dulcamara, and Echinacea are useful one.

External use

Combination of Phytolacca, Calendula, Apis, and Belladonna can be used as external use to apply over the udder, which can be used in cases of fissures, wounds, ulcers, congestions, hematomas, and to reduce inflammations.

Chronic fibrosed udder

Homeopathic remedies Conium maculatum 200c, Carboanimalis 200c and Silicea 200c as 40mm size pills @ 10 pills bid for 40 days.

Prevention and Control:**Dry cow therapy**

Intra mammary infusion of long-acting anti microbial agents at drying off provides the best treatment for subclinical mastitis due to contagious pathogens. Must adhere to milk withholding times after treatment with anti microbial agents to prevent milk drug residues, which is major public health issue.

Dry cow therapy (DCT) is associated with: Curing existing infections at dry off. Decreased risk of new infections during the dry period. Reduced risk of clinical mastitis in early lactation. Blanket dry cow therapy (BDCT; treating all quarters of all cows at dry off) has been a foundation of mastitis control for more than 50 years. Selective dry cow therapy (SDCT; treating only cows that are identified as infected at dry off) could be considered as an alternative to BDCT.

Internal teat sealants

Internal teat sealant (ITS) at drying off is a strategy used for the prevention of intramammary infections (IMI) during the dry period (DP), as it simulates the keratin plug's purpose, which is to prevent the access of pathogens into the mammary gland.

Hieifers - Intramammary infusions of beta-lactam antibacterial drugs 7–14 days before expected calving dates have been reported to reduce the prevalence of IMI at calving.

Clean milk production - includes hygienic milkers hand before milking, utensils hy

Permanently drying off chronically affected quarters

If a quarter does not respond to treatment and is classified as incurable, the affected animal should be isolated from the milking herd or the affected quarter maybe permanently dried off by inducing a chemical mastitis. Historically used methods, arranged in decreasing order of severity, are infusions of: o 30-60 mL of 3% silver nitrate solution o 20 mL of 5% copper sulfate



solution 100-300 mL of 1:500, or 300-500 mL of a 1:2000 acriflavine solution.

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GENE PYRAMIDING: A STRATEGY TO TACKLE ABIOTIC- BIOTIC STRESS

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Abstract

The increasing global population and the intensification of abiotic and biotic stresses, driven by climate change, threaten agricultural productivity and food security. To overcome these challenges, advanced molecular breeding approaches are being adopted, with gene pyramiding emerging as a key strategy. Gene pyramiding involves the incorporation of multiple stress-resistance genes into a single genotype, enhancing crop tolerance and stability. Techniques such as marker-assisted selection, marker-assisted backcrossing, and marker-assisted recurrent selection enable precise and rapid gene integration. Additionally, molecular gene stacking through co-transformation and re-transformation offers transgenic alternatives for trait enhancement. These methods have shown success in improving stress resistance in crops like rice, wheat, and cotton. However, the widespread application of these technologies is limited by high costs, the need for technical expertise, and infrastructure, particularly in developing regions. Increased investment and international collaboration are crucial to making these innovations accessible and ensuring sustainable food production under stress conditions.

Keywords: population, productivity, molecular breeding, resistance.

Introduction

The sustainability of the world's food supply is in threat due to the effects of abiotic and biotic stress on plant growth, development and output. Additionally, the ever-changing climate

constantly resets the environment in which plants can thrive by increasing the frequency and severity of shocks. Therefore, it is essential for plants to withstand these challenges in order to survive as the likelihood of plants experiencing abiotic and biotic stresses, alone or in combination, is likely to increase in the future (Mittler, 2006). According to the Food and Agriculture Organization (2009), in order to meet the growing population's demand for food, global food output must rise by 70% by 2050. It is estimated that worldwide annual loss due to biotic and abiotic stress is accounted to be 25% and 6-25% respectively (Pandey *et al.*, 2017). In order to simultaneously increase agronomic and nutritional qualities, sophisticated and quick crop-breeding methods are needed to meet the growing food demand. Since most crop-breeding techniques for biotic and abiotic stress resistance are based on the insertion of a single resistant gene into plants, emphasis is increasingly made on creating genotypes that are resistant to a variety of challenges by stacking many genes from several sources into a single plant. Gene pyramiding is one among the breeding techniques which is considered as long-lasting and reliable method to increase crop tolerance to both abiotic and biotic stresses.

Gene pyramiding

Gene pyramiding is the simultaneous selection and introduction of multiple genes in the plant. The occurrence of various environmental stresses has made it necessary to adopt modern technologies in order to protect the production potential of different crops under adverse growing conditions. The main issue with traditional breeding techniques for crop improvement is that it might be difficult to screen for undesirable genes that persist even after numerous backcross generations, in addition to the favourable genes that are still present. In comparison to conventional breeding, molecular technology advancements have enabled precise, sophisticated and quick breeding through molecular markers.

Gene pyramiding programs consists of three stages. The first step entails choosing of parents containing the desired gene. The second phase includes repeated backcrossing of F1 with one of the parents, which causes the desired genes to accumulate into a single genotype. The third stage, also known as homozygous or fixing stage, includes consistent selfing in order to create homozygous plants, which are frequently employed for variety development.

Molecular techniques in breeding programs

Molecular breeding can be broadly defined as the use of DNA-level genetic manipulation to enhance desired qualities in plants and animals. The molecular breeding technique

encompasses of genetic engineering or gene modification, molecular marker-assisted selection and genomic selection. However, the term "molecular breeding" is more frequently used to refer to "molecular marker-assisted breeding" (MAB), which is defined as the use of molecular tools, particularly molecular markers, in conjunction with linkage maps and genomics to improve and change plant or animal traits based on genotypic assays.

a) Marker Assisted Selection

A trait of interest is selected based on a marker (morphological, biochemical or DNA/RNA variation) linked to the trait of interest, rather than on the trait itself, in a process known as marker assisted selection (MAS). MAS is an effective gene pyramiding method, which involves combining numerous crucial genes into a single cultivar. Many important crops, including rice (resistance to bacterial blight, blast, flood and salinity and improved grain quality), wheat (resistance to leaf rust and powdery mildew), and cotton (resistance to insect pests) have successfully benefited from the use of marker-assisted selection for stress resistance development and quality improvement.

b) Marker-Assisted Backcrossing

Marker-assisted backcrossing (MABC) utilizes molecular markers to identify and select specific genes or QTLs responsible for resistance to certain traits. It involves transferring these genes or QTLs from a donor parent to enhance a desired trait in a superior cultivar or genotype. Unlike traditional backcrossing, MABC is considered as an efficient method to acquire results at a faster rate since it relies on marker alleles linked to the target genes or QTLs rather than phenotypic traits.

c) Marker-Assisted Recurrent Selection

Marker-assisted recurrent selection (MARS) is an enhanced method that combines genotype selection and intercrossing within a single growing season. This approach streamlines recurrent selection, accelerates the selection process, and allows for the integration of multiple advantageous genes.

Molecular Stacking

Molecular gene stacking or simultaneous gene pyramiding is another strategy where genes are stacked at the same time in a plant using transgenic approaches such as *Agrobacterium*-mediated transformation or by biolistic methods (Keshavareddy and Kumar,

2018). The molecular gene stacking can be achieved in plants via two routes: co-transformation or re-transformation.

a) Co-transformation mediated gene pyramiding

Co-transformation, a highly efficient method of introducing multiple genes into plants. It can be achieved through multiple plasmid co-transformation with separate plasmids or individual DNA fragments. Alternatively, it can be achieved by single plasmid co-transformation with linked transgenes, each having its unique promoter and transformed together into the plant via *Agrobacterium*-mediated transformation or the biolistic method (Segolela *et al.*, 2019). There are difficulties in constructing complex plasmids containing multiple gene cassettes with identical promoters. GAENTRY (Gene Assembly in *Agrobacterium* by Nucleic acid Transfer using Recombinase technology) is a cost-effective and reliable method that efficiently assembles and maintains very large T-DNAs by stacking genes in sequence. This process ensures the production of high-quality transgenic events with a low copy number and no contamination from the backbone.

b) Re-transformation mediated gene pyramiding

Re-transformation involves the repeated transformation of a transgene-carrying plant with multiple genes to create multi-trait or combined trait events. This process often results in transgenes being inserted at different locations, necessitating distinct selectable markers for each event. This method is primarily used for crops that are difficult to propagate sexually, but its use is limited due to the need for multiple selectable markers and the challenges of inducing and managing transgenes.

Conclusion

To meet the global food demands and combat the harmful effects of various stresses on crop productivity, it is important to protect crops from both biotic and abiotic stress. The traditional plant breeding has evolved with the inclusion of molecular markers and other strategies, facilitating the integration of stress-tolerant genes into crops to enhance yield, stress tolerance and nutritional qualities. Molecular marker genotyping streamlines the selection process, reducing the time needed to evaluate and incorporate genes into desired cultivars. Exploring marker-assisted selection gene pyramiding can help mitigate the risk of reduced crop yields and quality under stress conditions. This approach has already been successfully applied in certain potato, rice, wheat, and barley varieties. Despite significant progress, there are certain

challenges particularly in making marker-assisted gene pyramiding cost-effective and fostering technical collaboration and financial support to enable its wider adoption in developing countries.

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PHYSIOLOGY OF FRUIT DEVELOPMENT IN VEGETABLE CROPS

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Abstract

A fruit is a matured ovary and its development involves mainly of four major phases like fruit set, cell division, cell expansion and ripening. Most of the fruit follows the sigmoid growth curve pattern and a few fruits follows double sigmoid curve growth pattern as in case of peaches, grapes, figs etc. and Kiwi has triple sigmoid growth curve pattern. Fruit set is achieved by the proper pollination and full completion of fertilization but in some plants the fertilization is bypassed resulted in the formation of seedless fruits. Fruit set can be regulated by two major model such as sugar signalling model and multihormonal model (Ruan *et al.*, 2012). Fruit growth and development are regulated by a number of biotic and abiotic factors. Many genes and growth regulators like auxin, gibberellins, cytokinin, abscisic acid, ethylene and some other regulators play a major role in the development and ripening of the fruits of vegetables (Crane 1964, 1969; Nitsch 1970).

Keywords: fruit development, fruit set, cell division, cell expansion, ripening, genetic regulation, hormonal regulation, growth curve.

Introduction

The term fruit is derived from the Latin word “fructus” which means to produce and it is botanically defined as the matured ovary. Fruit is the major part of the plant of flowering plants which is formed from the ovary and protects the seed inside it which is formed from the ovule.

Botanically, it is called as the seed bearing structure in angiosperms (Lewis, Robert A., 2002). Most of the vegetable crops bears fruits as a economic part and has many nutritional values and various health benefits. Most of the vegetables like cucurbits, tomato, brinjal, bhendi, melons, peas etc. has fruits as its edible parts. Such fruit development can be obtained by undergoing various growth stages like cell division, cell elongation, maturation and ripening. This development of fruits can be acquired by a series of complex physiological, biochemical and genetic processes.

FRUIT GROWTH DYNAMICS

Fruit growth commonly follows the sigmoid growth curve patterns due to the changes occurring in the development of fruits by increasing in the mass or volume from pollination to the maturity stage. Mostly sigmoid growth pattern is noticed in most of the fruits of vegetable crops, in some cases double sigmoid growth curve is noticed in some of fruit crops like peach, grapes, figs etc. and triple sigmoid growth patten is noticed in kiwi fruit. At the cellular level, ontogeny alters the relative amounts of cell division and growth, and changes in the percentage of air space also contribute to volume increase (Brummell., 2013).

PHASES OF FRUIT DEVELOPMENT

The phases involved in fruit development are described briefly in the following.

- Pre pollination stage – This stages involves the development of floral and fruit primordia (ovary and ovule) initiation.
- Pollination stage – It involves the transfer of pollen grains from the anther of the flower to the stigma of the flower. This process can be occurred either by self pollination (transfer of pollen grains from the anther of a flower to the stigma of the same flower or another flower of the same plant) or by cross pollination (transfer of pollen grains from the anther of a flower to the stigma of another flower of another plant).
- Fertilization – It is the fusion of male and female gametes and the formation of zygote.
- Fruit set – After successful pollination of ovary and fertilization of ovule and further development occurs. Successful fertilization of the ovule – followed by cell division and cell enlargement, results in fruit growth. If the pollination and fertilization didn't occur properly, it results in senescence.
- Post fruit set – The post fruit set phase involves either of the two following cases. In *Lycopersicum esculentum*, the growth occurs entirely by cell enlargement after the cell

division phase. In *Lycopersicum pimpinellifolium*, cell division accompany cell enlargement throughout the period of fruit growth (Crane 1964).

- Fruit maturation
- Fruit ripening

TOMATO FRUIT DEVELOPMENT

Tomato fruit takes about 40 to 70 days from fertilization to red ripe stage. It involves four phases.

PHASE I: The initial stage of development involves floral development, pollination, fertilization and fruit set. This phase completes in about 7 – 8 days.

PHASE II: This phase involves active cell division for about 7 to 14 days (Mapelli *et al.*, 1978). The fruit growth is slow in this phase reaching upto 10% of final fruit fresh weight of the fruit.

PHASE III: This phase involves expansion of the divided cell which takes about 3 – 5 weeks and the maximum fruit weight is attained in this phase (Ho and Hewitt., 1986). The maximum fruit size attained finally depends upon the number of cells established in the phase II (Ho., 1996).

PHASE IV: Ripening of the fruit takes place in this phase which involves slow growth rate and intense metabolic changes occurs.

GENETIC REGULATION OF FRUIT DEVELOPMENT:

Various genes are involved in the development of fruit have been discussed as below. Clavata – Wuschel feedback loop plays a major role in the genetic regulation of the development of the fruits. This is a regulatory mechanism in the plant mechanism where clavata (CLV) signalling pathway negatively regulates the expression of the wuschel (WUS) gene, thereby maintaining a stable population of the stem cells within the shoot apical meristem (SAM) by balancing stem cell proliferation and differentiation. When WUS activity increases, CLV signalling is triggered, leading to decrease in WUS expression, thus resulting in the controlling of the stem cell numbers. The signalling peptide CLV 3 directly interacts with the leutin rich repeat receptor kinases like CLV 1 and CLV 2 to activate the signalling cascade that negatively regulates the stem cell promoting transcription factor WUS (Jennifer C., 2018). There are many genes that regulate the fruit development during the stages of meristem size and gynoecium identity, fruit morphology and fruit ripening.

I.GENES INVOLVED IN MERISTEM SIZE AND GYNOECIUM IDENTITY

Some of the genes like FIN, FAB 2, RRA3a, FAS, LC, TAG 1 are involved in the formation of floral primordia.

- FASCIATED INFLORESCENCE (FIN), FASCIATED AND BRANCHED 2 (FAB 2) and REDUCED RESIDUAL ARABINOSE 3a (RRA3a) are found to be newly emerged components of the CLV-WUS pathway which helps in maintaining the balance of stem cell differentiation and proliferation (Xu *et al.*, 2015).
- FAS is the mutated gene obtained by inversion disturbing the tomato CLV 3 gene, therefore making the stem cell to over proliferate and aids in the production of large size fruits (Xu *et al.*, 2015; Rodríguez-Leal *et al.*, 2017).
- LC is associated with the downstream of WUS, thus altering the proliferation and differentiation of the cells. The joint action of the *fas* and *lc* gene helps in the development of the large fruited cultivars (Tanksley, 2004; Barrero *et al.*, 2006). It also blocks the binding of TAG 1 gene to SIWUS 3' regulatory region, thus results in the development of large sized fruits (van der Knaap *et al.*, 2014).
- TAG 1 – The downregulation of TAG 1 gene results in the alteration in the carpel development and the development of the indeterminant character of the tomato plants (Pnueli *et al.*, 1994; Pan *et al.*, 2010; Gimenez *et al.*, 2016).

II.GENES INVOLVED IN FRUIT MORPHOLOGY

The genes like OVATE, SUN, EJ 2, CNR, SIKLUH, CSR are involved in determining the fruit morphological characteristics like fruit shape and weight. OVATE and SUN gene also plays a major role in the imparting fruit morphological characters in addition to CLV-WUS pathway.

- OVATE – By the expression of this gene, more cells are produced in the proximo-distal end direction by changing the cell division pattern during the earliest stages of gynoecium development, thus resulting in the development of elongated fruits (Ku *et al.*, 1999; Liu *et al.*, 2002; Rodríguez *et al.*, 2011).
- SUN – This gene increases the cell division along the proximal distal axis and cell elongation immediately after fertilization (Xiao *et al.*, 2009; Wu *et al.*, 2011; van der Knaap *et al.*, 2014).
- Enhancer of J2 (EJ 2) – is involved in the determining fruit shape and develops slightly elongated fruits with branched inflorescence and jointless pedicels (Soyk *et al.*, 2017).

- Cell number regulator (CNR) – This gene increases the ovary size and enlarge the placenta and columella fruit tissues, usually acting in the early during the development of gynoecium (Cong *et al.*, 2002; Gonzalo *et al.*, 2009).
- SIKLUH – increases the fruit weight by enhancing the expression of this gene in the meristems and young flower bud tissues (Chakrabarti *et al.*, 2013).
- Cell size regulator (CSR) – This gene controls the pericarp cell size and also involved in shoot elongation and phloem/xylem histogenesis (Huang and van der Knaap, 2011; Mu *et al.*, 2017).

III.GENES INVOLVED IN FRUIT RIPENING

After completion of the fruit development, ripening of fruit initiates. The genes like RIPENING INHIBITOR (RIN) (Vrebalov *et al.*, 2002), COLORLESS NON-RIPENING (CNR) (Manning *et al.*, 2006), and NON-RIPENING (NOR) (Yuan *et al.*, 2016), SIACS 2, NR, PG, TBG 4, MAN 4, EXP 1, PE, PSY 1, PE, XET etc., are involved in the ripening of fruits.

- RIN – This gene encodes a SEPALLATA (SEP) – class MAADS box transcription factor which acts as a regulator of the fruit ripening. *rin* mutant involved in repressing ripening (Vrebalov *et al.*, 2002). RIN binds to the demethylated promotor regions of ethylene biosynthesis genes such as SIACS 2, SIACS 4, SIACO 1, NR whose products are involved in fruit softening. RIN positively stimulates the expression of CNR gene (Klee and Tieman, 2002; Ito *et al.*, 2008; Fujisawa *et al.*, 2011; Martel *et al.*, 2011; Shima *et al.*, 2013; Ito *et al.*, 2017).
- CNR gene involved in positive regulation of ripening related genes (Cardon *et al.*, 1999; Manning *et al.*, 2006). *cnr* mutation – increases cytosine methylation in the promotor of a SQUAMOSA promotor binding protein encoding gene, which strongly decreases the gene expression and produces colorless fruits with an altered pericarp texture (Manning *et al.*, 2006). During ripening, the CNR promotor is demethylated; but in *cnr* mutants, the promotor remains hypermethylated, preventing RIN from binding to it (Zhong *et al.*, 2013).
- NOR gene involved in fruit ripening whereas *nor* mutant – 2 bp deletion in the NOR coding gene – results in abnormal ripening (Tigchelaar *et al.*, 1973; Martel *et al.*, 2011; Osorio *et al.*, 2011). This mutant gene inhibit the multiple metabolic activities and prolongs the fruit shelf life (Kumar *et al.*, 2018).
- Other genes like SINAC 1, SINAC 4 & NOR like 1 – involved in the regulation of fruit

ripening (Ma *et al.*, 2014; Zhu *et al.*, 2014; Meng *et al.*, 2016).

HORMONAL REGULATION OF FRUIT DEVELOPMENT

Before anthesis, when the ovary has reached its size, ABA and ethylene work to stop growth within the ovary to maintain a temporary protection and dormant state (Gillaspy *et al.*, 1993; Azzi *et al.*, 2015). After the successful pollination and fertilization of the ovule occurs, ovary growth resumes and fruit and seed develops (Azzi *et al.*, 2015). The changes are associated with the decrease in ABA and ethylene concentration, increase in auxin, gibberellin and cytokinin (de Jong *et al.*, 2009; McAtee *et al.*, 2013; Shinozaki *et al.*, 2015; Shinozaki *et al.*, 2018a). GAs produced by pollen increases the auxin production in the ovary, which acts a signal for fruit set and cell division (Gillaspy *et al.*, 1993; de Jong *et al.*, 2009). Active fruit growth (pericarp cell division and elongation) promoted by biosynthesis of auxin in the developing seeds and GAs in the pericarp (Obroucheva, 2014). Exogenous application of these hormones leads to parthenocarpic fruit development (Fos *et al.*, 2000). Auxin signalling pathway play a major role in the process of cell division and cell expansion. When auxin is present, auxin is transported to the plant cytoplasm. It binds with the TIR 1 (Transport inhibitor response 1) region, it also activates F box complex and TIR 1 also gets activated (Azzi *et al.*, 2015). This TIR 1 also acts as a ligase that starts adding poly ubiquitin to Aux/IAA. After the attachment happens it distances the inhibitor Aux/IAA from the Auxin response factor (ARF) and to be degraded by 26S proteolysis complex (Azzi *et al.*, 2015). When complete degradation is done, ARF is free now and actively binds to the regulatory region. As a result transcription of the structural gene into mRNA occurs. This mRNA is translated and make proteins for auxin response elements and allowing the cell to divide and differentiate (Azzi *et al.*, 2015).

Conclusion

We can conclude that the development of fruit is a complex and dynamic process that can be influenced by various factors like genetics, environmental conditions and hormonal regulation. Understanding the various stages of fruit growth from the fertilization to the ripening of the fruit provides insights into key physiological mechanisms that determine fruit yield and quality.

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TYPES OF MULBERRY AND ITS HEALTH BENEFITS

Article ID: AG-VO5-I06-48***Kowsalya, R., Priyadharshini, P., Swathiga, G. Thangamalar, A**

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Introduction

Mulberry is a tree species primarily used as host plant for feeding silkworms (*Bombyx mori*). It bears fruit on seasonal basis. In India, particularly in the south, there's a two-fold fruiting season. The first occurs from October to November, and the second from March to May. Mulberries are a type of berry, specifically an aggregate berry. This paper highlights the classification of mulberry fruits and its health benefits in human.

Botanical Classification of mulberry

Mulberries belong to the genus *Morus* within the Moraceae family, which also includes figs and breadfruit.

Types of mulberry

There are three types of mulberry based on the colour of dormant buds

- White mulberry (*Morus alba*)
- Red mulberry (*Morus rubra*)
- Black mulberry (*Morus nigra*)

Development of mulberry fruit

Fruit develops from the ovary of multiple individual flowers which then fuse together to form a single fleshy fruit with many tiny, seed-bearing parts.

Appearance of fruits

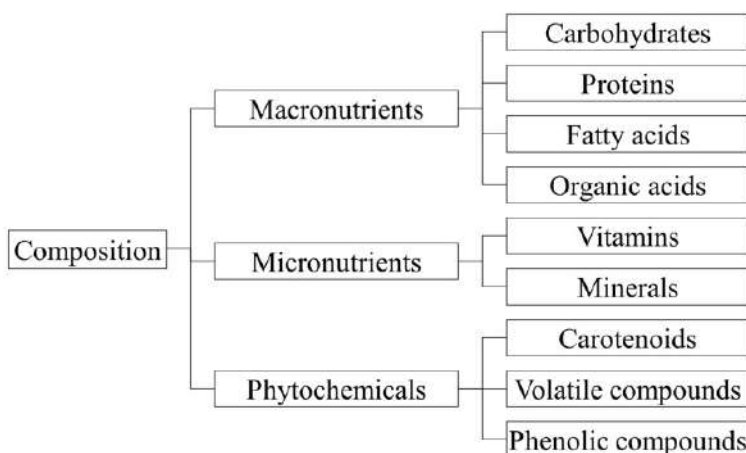
They are elongated, berry-like fruits, resembling small, slender blackberries.



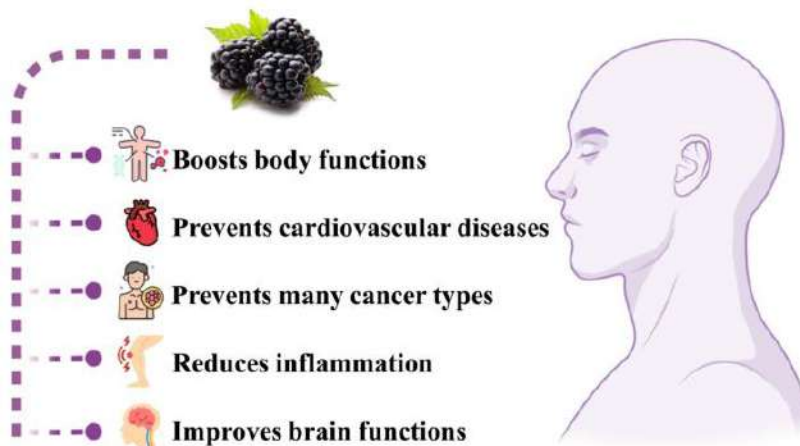
Edible Parts

The entire fruit, including the fleshy part and tiny seeds is edible and can be consumed as fresh or dried fruits. Mulberries are also used in various culinary applications, including jams, jellies, pies, desserts, and beverages.

Composition of mulberry fruits



Health benefits of mulberries



WHITE MULBERRY (*Morus alba*)

White mulberry is native to Asia peculiarly India and China. *M. alba* plant is also known as Tutam in Sanskrit, Tut in Hindi, Mulberry in English, Malbari in Malayalam, and Musukette in Tamil. This plant is moderately sized, three to six meters tall and categorized as a shrub or tree and is the most widely cultivated species throughout the



world. In Chinese medicine, *M. alba* plant provides a long list of medicinal benefits. While there are a few white-fruited cultivars, most cultivars bear ripe pink to black fruit.

Popular varieties of white mulberry

- Beautiful Day produces a white, small and very sweet mulberry
- Dwarf Ever-bearing is often falsely identified as *Morus nigra* because of its dark colour. It has small but sweet fruit. It produces fruit for several months.
- Dwarf mulberry Issai produces large, dark fruit of a lesser quality.
- Florida Giant produces a dark fruit. It grows quickly and bear fruits later than most alba.

Compositon of white mulberry fruits

Water	:	86 - 89%
Carbohydrates	:	9.8%
Protein	:	2.1%
Fat	:	0.4%
Organic acid		Malic acid, succinic acid, lactic acid, fumaric acid, citric acid, tartaric acid and acetic acid
Vitamins	:	Vitamin C and K
Minerals	:	Potassium, calcium, phosphorous, sodium, zinc, copper, iron and selenium
Other compounds	:	Flavonoids, anthocyanins, alkaloids and polysaccharides
Uses	:	Nourish blood, treat anemia, fatigue, and prevent premature graying of hair. Besides its fruit, all its parts offer medicinal benefits in treating asthma, edema, cough, bronchitis, insomnia, influenza, diabetes, eye infections, and nose bleeding. It has diuretic, laxative, antibacterial and anthelmintic properties

RED MULBERRY (*Morus rubra*)

Morus is a Latin word for mulberry and rubra is a Latin word for red. Red mulberry is found in damp soils, flood plains, and moist sites of Eastern and North America, South Florida, West Texas, Minnesota, Ontario, and mid-Atlantic regions. In different areas, different parts of this plant are used to treat diseases. Albama and Indians are using its root to treat urinary tract issues, its juice is being used by Rappahannock community to treat ringworm by rubbing over the skin, Cherokee uses its bark to eliminate intestinal worms by steeping its bark and ingesting the liquid lastly, its root bark is used in Meskwaki to treat many ailments. Its cultivators and hybrids are known for flavourful fruit with an acidic undertone. Red Mulberry performs better in less sunny places than white mulberry. Fruit yield is inversely proportional to the amount of sunlight.



Popular varieties of red mulberry

- Gelso Rosso is a slow-growing Italian variety of the red mulberry with a final height of only 3.5 m
- Illinois Overbearing is a cross of white and red mulberry
- Wellington is a variety of white and red mulberry bred by Richard Wellington in New York. It is a very fertile variety with aromatic, black fruits and a long harvest time.

Composition of red mulberry fruits

Water	:	88%
Carbohydrates	:	10%
Protein	:	1%
Fat	:	Less than 1%
Organic acid	:	Malic acid, citric acid, tartaric acid, succinic acid, and fumaric acid
Vitamins	:	Vitamin C, and also contains Vitamin A, B1, B2, B3, B6, folate, E, and K
Minerals	:	Potassium, calcium, iron, phosphorus, sodium, and magnesium

Other compounds	:	Anthocyanins (contributing to their red color), and polyphenols, which have antioxidant properties.
Uses	:	Boosting immunity, aiding digestion, improve heart health, protect against cellular damage, potentially reducing the risk of chronic diseases

BLACK MULBERRY (*Morus nigra*)

Black mulberry is native to Asia peculiarly Persia, Turkish, and Greek. It is the mulberry species with the slowest growth rate and the longest lifespan. It is innate in humid, sub-tropical and pleasant zones in Asia, Europe, North America, South America, and Africa. Its sensory evaluation indicates that it has sweet, sour, musky and woody flavours and has woody, fresh aroma physiognomies, dark black colour of the fruit due to the presence of anthocyanins. Its barks, leaves and berries all provide medicinal properties. Berries are used for treating inflammation and blood bleeding. Bark is used for treating tooth-ache and leaves are used as an antidote. In Europe, leaves of *M. nigra* have been used to stimulate the production of insulin in people with diabetes mellitus. In Turkey, it has been used in folk medicine to treat fever, buffer the liver, support joints, manage blood pressure and assist in the passage of urine.



Popular varieties of black mulberry

- Agate mulberry fruits ripen in late summer and taste sweet and aromatic.
- Black Persian is a Central Asian variety with very large black fruits up to 6 cm long and 3 cm wide.
- Kaester is a high-yielding mulberry variety from Los Angeles with very sweet, black red fruits.

Compositon of black mulberry fruits

Water	:	88%
Carbohydrates	:	9.8%
Protein	:	1.4%
Fat	:	0.4%

Organic acid	:	Malic acid, Citric acid, tartaric acid, and oxalic acid, fumaric acid and succinic acid
Vitamins	:	Vitamin C
Minerals	:	Magnesium, iron, sodium, potassium, and calcium
Other compounds	:	Anthocyanins, flavonols and phenolic acids, dried mulberry fruits contain high amount of fibre, protein, and carbohydrates
Uses	:	Reduces blood sugar level, laxative, managing constipation, menopause issues, running nose, anti-inflammatory, anti-cancerous, antiviral, and have cardiovascular properties.

Commercial products produced with mulberry fruits

- **Juices and Beverages:** Mulberry fruits are used to prepare refreshing fruit juices and beverages due to their sweet-tart taste
- **Jams and Jellies:** Mulberry fruits are a popular ingredient in jams and jellies
- **Wines and Vinegar:** Mulberry fruits can also used to produce fermented products like wines and vinegar
- **Pies, Tarts, and Crumble:** Mulberries can be incorporated into baked goods like pies, tarts, and crumbles
- **Mulberry Ice Cream:** This frozen dessert is a popular way to enjoy mulberries and most popular in Thailand
- **Other Products:** Mulberries can also be used in syrups, squashes and even in yogurt. They can also be dried, ground, and added to flour as a nutritional amendment.

Conclusion

Mulberry fruits provide a wide range of health benefits due to their rich nutrient content and bioactive compounds. These fruits are considered as a valuable source of antioxidants. Some studies suggesting that they may help to reduce the risk of chronic diseases like cancer, diabetes and heart diseases. However, more human intervention studies are needed to extend these benefits and the mechanisms.



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SYNBIOTICS IN AQUACULTURE: ENHANCING FISH HEALTH AND PRODUCTIVITY

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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).

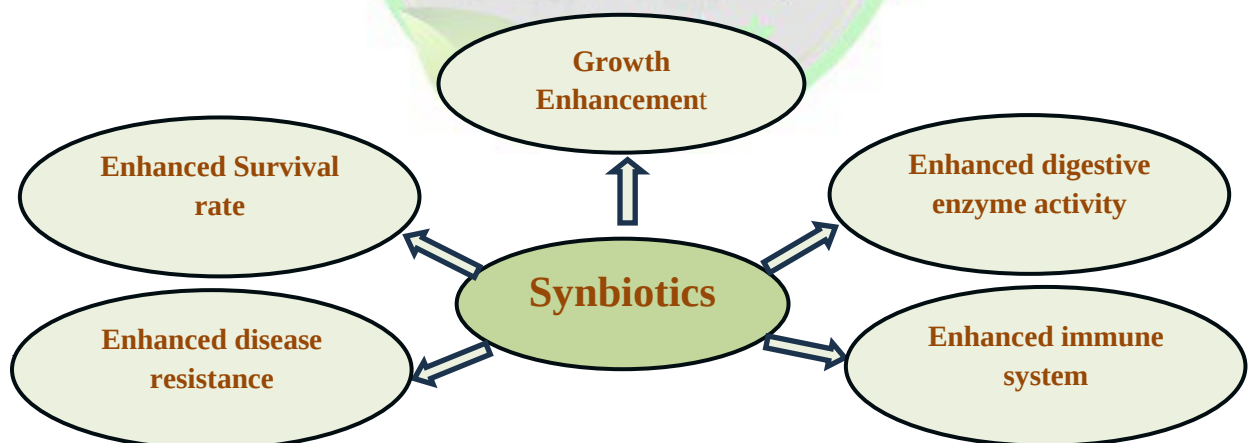


Benefits of synbiotics in aquaculture

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).



Challenges and Future Directions

Practical application of synbiotics must undergo a well-defined and precise methodology. This process requires thorough 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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THE ENVIRONMENTAL AND DIGITAL WORLD IMPACT OF THE E-WASTE, ENERGY CONSUMPTION.

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Abstract

Electronic waste, often known as E-waste, is a category of refuse generated from electronic devices. In today's industrialized world, waste management has become one of the most complex and rapidly growing challenges. E-waste consists of obsolete or end-of-life electronic equipment such as computers, laptops, televisions, generators, DVD players, mobile phones, refrigerators, and other similar items. These devices are usually discarded by their original users due to their limited lifespan or functional obsolescence. Hence, this review presents a compendium of various sources of E-waste, environmental hazards, its composition and characterization, E-waste scenarios in India and global world. Now, the situation is alarming as a huge quantity of waste is generated by India as well as other countries. The condition in India is much worse because about 80 percent of the e-waste generated in the US is exported to India, China and Pakistan under the name of charity. Only 3% of total WEEE- E (waste from electrical and electronic equipments) waste generated is recycled properly in India. It causes both environmental as well as health problems. Number of laws are framed but none is able to stop this informal recycling. In this paper, national and international e-waste scenario is discussed along with hazards caused by e-waste and bit about its recycling. During the finding it has been found that there is an urgent need to address the issues related to E-waste in India in order to avoid its detrimental future consequences.

Keywords: E-waste management, Environmental pollution, Human health, E-waste recycling

Introduction

The digital era has transformed communication, employment, education, and entertainment. However, the rapid expansion of digital gadgets and infrastructure has raised significant environmental issues. Two of the most significant challenges are electronic waste and the excessive energy consumption of digital technologies. There is a need for e-waste management as e-waste components may cause severe health risks and environmental damage, when crude, unscientific methods are applied for recovery of useful components. There is a need to encourage recycling of all useful and valuable material from e-wastes to preserve the natural resources. Most of the developing countries are suffering with the rapidly growing problems of e-waste and have to have sound e-waste management systems for end of life ICT products to avoid the threat on environment and mankind. The rapid growth of ICT, frequent innovations and technological changes are resulting in shorter life span of ICT equipment. Moreover in developing countries the quantity of imported disused Electrical and Electronic equipment (EEE) is uncontrolled. So the volume of e-waste has also increased drastically in developing and developed nations. At the same time, it is encouraging that every nation, along with going for the development in the ICT sector, is also working for 'going green' by taking care of issues like efficient use of natural resources, minimization of e-waste, sustainable recycling of e-waste and development of products with minimum use of hazardous substances.

WEEE (Waste from Electrical and Electronic Equipment).

WEEE is highly diverse, both in terms of the materials it contains and the manufacturing processes used to produce it. This complexity poses significant challenges for recycling, disposal, and environmental management. Simultaneously, the exponential growth in digital data and services has led to increased energy demand, especially in data centers and network infrastructure. Together, e-waste and digital energy consumption represent critical environmental challenges that must be addressed to ensure a sustainable digital future.

E-Waste: A Growing Global Concern

E-waste refers to discarded electronic devices such as smartphones, computers, and televisions. According to the Global E-waste Monitor, over 50 million metric tons of e-waste are generated annually. This waste often contains toxic materials like lead, mercury, and cadmium, which can harm ecosystems and human health if improperly handled.

Effects of e-waste on human health and environment:

e-waste is highly complex to handle because of its composition. It is made up of multiply components some of which contain toxic substances that have an adverse impact on human health and environment if not handled properly that is if improper recycling and disposal methods are deployed. So there is a need for appropriate technology for handling and disposal of these chemicals. Basel Convention characterizes e-waste as hazardous when they contain and are contaminated with mercury, lead, cadmium, polychlorinated biphenyl etc. Wastes containing insulation or metal cables coated with plastics contaminated with or containing ,lead, coal tar, cadmium, Polychlorinated Biphenyl (PCB) etc are also characterized as hazardous wastes. Also precious metal ash from printed circuit boards, glass waste from cathode-ray tubes, LCD screens and other activated glasses are classified as hazardous wastes.

Impact of Digital Infrastructure

Digital infrastructure plays a crucial role in facilitating the adoption and expansion of advanced digital technologies including big data, the Internet of Things (IoT), artificial intelligence (AI), and blockchain. Its influence is inherently multidimensional, encompassing economic, energy- related, and environmental aspects. A growing body of literature has explored these impacts across various contexts and regions (Chen et al., 2021; Liu et al., 2021).

From an economic standpoint, digital infrastructure significantly supports national development and industrial transformation. For instance, Wu and Yu (2022) provided empirical evidence that the digital economy has substantially bolstered China's economic growth and productivity. Similarly, Chen et al. (2022) highlighted that AI adoption positively influences the upgrading of the equipment manufacturing sector, with technological innovation serving as a key mediating factor. Further, Li et al. (2023) found that AI applications have enhanced corporate innovation efficiency, though this effect varies across different organizational contexts.

Key facts

- E-waste is one of the fastest growing solid waste streams in the world .
- In 2022, an estimated 62 million tonnes of e-waste were produced globally. Only 22.3% was documented as formally collected and recycled .
- Lead is a common substance released into the environment when e-waste is recycled, stored or dumped using informal activities, including open burning .
- Informal e-waste recycling activities may have several adverse health effects. Children

and pregnant women are particularly vulnerable. The report "Recycling - from E-Waste to Resources" issued at a meeting of the Basel Convention estimated that, by 2020 in China and South Africa, the e-waste from computers would increase between 200 and 400% over 2007 figures and 500% in India. It was also estimated that by 2020 in India the amount of e-waste from mobile phones would be 18 times higher than the 2007 figures and 7 times higher in China. Basel Action Network stated that 50- 80% of e-waste generated in USA is exported to India, China, Pakistan, Taiwan and African countries.

Key Issues

- Data Centers: Responsible for about 1–2% of global electricity use.
- Carbon Emissions: Much of the energy comes from fossil fuels, contributing to climate change. Always-On Culture: Devices and networks running 24/7 significantly increase demand.

Management of e-waste

A smart e-waste management system for developing countries have to assess the e-waste situation, recognize that e-wastes are a complex mixture of hazardous and non-hazardous substances and materials and need to define the integral e-waste management system taking into consideration the EEE market penetration, life cycle of ICT equipment, financing mechanisms etc. The main aspects to be taken into account when framing ICT waste management guidelines for developing countries are:

Policy and regulations covering import and export of EEE and WEEE in accordance with the rules of each country and with international legislation. Defining responsibilities of prime stakeholders at the level of government, supply chain, consumers of ICT equipment and entities for disposal of waste Extended producer responsibility (EPR) where the manufacturer's responsibility for its ICT equipment extends throughout the various stages of that equipment's life cycle with internalizing the cost of managing the equipment at end of life Responsible information system to have data on ICT equipment in market, disused EEE management and WEEE management and to have control on the monitoring and future planning Promoting employment and training for the informal sector engaged in recycling and recovery of the material.

Conclusion

The digital revolution has brought undeniable benefits, but its environmental costs must

be addressed. Tackling e-waste and high energy consumption requires coordinated efforts from governments, industries, and consumers. By adopting sustainable practices, it is possible to minimize the ecological footprint of the digital world.

To move toward sustainability and the achievement of SDGs, particularly SDG 12 (Responsible Consumption and Production) and SDG 13 (Climate Action), colleges, universities, and departmental institutions must play a proactive role. They are essential not only in research and innovation for green technologies but also in educating students about the environmental impact of digital technologies. Integrating sustainability education into curricula, promoting e-waste awareness drives, and implementing green campus initiatives can have long-term social and environmental impact (UNESCO, 2022).

Additionally, the way forward involves:

Policy development for e-waste regulation and energy-efficient infrastructure.
Strengthening extended producer responsibility (EPR) mechanisms.

Promoting digital sobriety—the conscious reduction of digital resource use. Supporting informal sectors through training in safe recycling techniques.

Collaboration between governments, educational institutions, industries, and civil society is crucial. By embedding sustainability into digital practices, and fostering an eco-conscious culture, we can ensure that the benefits of the digital age do not come at the cost of planetary health.

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ROLE OF SPIDERS IN REGULATING INSECT PESTS IN AGRICULTURAL ECOSYSTEM

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Introduction

Spiders and insects have a complex connection in agricultural systems, with spiders serving as natural predators and pest controllers for many insects. This link is critical for sustaining healthy and productive agricultural ecosystems while lowering dependency on chemical pesticides. Many studies in India, notably on rice and other crops, have demonstrated spiders' predatory activity and influence on insect pest populations.

Spiders as Predators

Spiders are significant predators of a variety of insect pests, including aphids, caterpillars, beetles, and leafhoppers. They can help manage insect populations, hence minimizing crop damage and output losses.

Spider Diversity and Function

Spiders' efficiency as pest controllers may be impacted by the variety of spider species found in an agricultural area. Certain spiders may be better at controlling particular pests than others, and different spider species may feed on different kinds of insects.

Spider Guilds

Spiders are often separated into guilds, such as web-building, ground-runner, and stalker, according to their preferred habitats and hunting techniques. These guilds may affect pest populations in different ways and feed on various kinds of insects.

Impact of Pesticides

Spider populations may be adversely affected by the use of pesticides in agriculture, which may lessen their diversity and abundance as well as their ability to effectively control pests.

Importance of Spiders in Sustainable Agriculture

Sustainable agricultural methods that reduce the use of pesticides and preserve beneficial insects and spiders can be promoted by acknowledging the role of spiders as natural pest control agents.

Ecological Role of Spiders

Spiders are predatory arthropods that are present in almost all terrestrial environments. Their inherent ability to manage populations of different insects, especially pests, makes them significant biological control agents. In gardens, woodlands, and agroecosystems, their function is particularly crucial.

Types of Interactions

A. Direct Predation

Spiders capture, kill, and consume insect pests using:

- Web-trapping: e.g., orb-weaver spiders (Araneidae) trap flying pests like whiteflies and moths.
- Ambush hunting: e.g., crab spiders (Thomisidae) hide in flowers or foliage and catch visiting insects like aphids or beetles.
- Active hunting: e.g., wolf spiders (Lycosidae) and jumping spiders (Salticidae) actively stalk and attack mobile prey such as caterpillars and larvae.

Target Pest Groups:

Pest Type	Examples	Spider Predators
Sap-sucking pests	Aphids, thrips, whiteflies	Web-weavers, jumping spiders
Leaf chewers	Caterpillars, beetle larvae	Wolf spiders, crab spiders
Dipterans	Mosquitoes, leaf miners, gnats	Orb-weavers, funnel web spiders

B. Non-Consumptive Effects ("Ecology of Fear")

Even when spiders don't eat pests, their **presence can alter pest behaviour**:

- Less mobility or feeding because of a fear of predators

- Avoid locations with spider webs or silk.
- Stress-induced reproductive reduction in pest populations

This indirect impact can suppress pest damage even without significant spider feeding.

3. Spider Hunting Strategies and Niches

Spider Type	Habitat/Behaviour	Pest Target
Orb-weaving spiders	Build vertical webs in open areas	Flying insects (moths, flies)
Sheet-web spiders	Build horizontal webs on ground	Small crawling insects
Jumping spiders	Visual hunters on leaves	Aphids, beetles, leafhoppers
Wolf spiders	Ground-dwelling hunters	Caterpillars, beetle larvae
Crab spiders	Camouflaged on flowers	Pollinators, aphids, flies

4. Spiders in Agricultural Ecosystems

Contribution to Pest Management:

- Maintain pest populations below economic thresholds.
- Provide year-round predation, unlike some other biological agents that are seasonal.
- Can complement other control methods, such as parasitoids and selective insecticides.

Examples:

- In rice fields, wolf spiders help control plant hoppers.
- In cotton fields, lynx and jumping spiders prey on bollworms and aphids.
- In greenhouses, certain spiders are introduced or encouraged as part of integrated pest management (IPM).

5. Research Insights

- Studies demonstrate that fields with increased spider diversity had reduced insect outbreaks.
- Conservation biological control (e.g., conserving hedgerows, limiting pesticide use) increases spider populations.
- Spiders can function as markers of ecosystem health and agro-ecological balance.

6. Limitations and Challenges

Issue	Description
Generalist diet	May prey on beneficial insects like pollinators or parasitoids



Issue	Description
Sensitivity to pesticides	Broad-spectrum insecticides reduce spider abundance and disrupt control
Cannibalism and competition	Intra-guild predation can limit their effectiveness
Variable prey preferences	Not all spiders are equally effective against all pests

Summary

Predation and intimidation are the main ways that spiders engage with insect pests. Particularly in natural or low-input farming systems, these interactions aid in lowering insect numbers and damage. However, farming methods, spider variety, and habitat structure all affect how effective they are.



ENHANCING FARMER'S INCOME: ROLE OF VALUE ADDITION OF FRUITS AND VEGETABLES

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Abstract

Enhancing farmers' income through value addition of horticultural commodities is a pivotal strategy for sustainable rural development. In India, a significant portion of horticultural produce is lost due to perishability and inadequate processing infrastructure. Implementing value addition techniques can mitigate these huge losses and can extend shelf life, thereby increasing marketability and profitability. As per reports, farmers engaged in value-added processing activities experience higher income levels compared to those selling raw horticultural produce. However, challenges such as lack of infrastructure, technical knowledge, and market access persist. Addressing these barriers through training programmes, infrastructure development, and market linkages is essential to fully realize the potential of value addition in agriculture. Overall, value addition not only enhances farmers' income but also contributes to food security, rural employment, and economic resilience.

Key Words: Famer's income, Inadequate processing, Value addition, Profitability, Food Security

Introduction

Agriculture remains the backbone of rural livelihoods, especially in developing economies where a significant portion of the population depends on farming for sustenance. However, despite their crucial role, most of the farmers struggle with low and unstable incomes, due to limited access to markets, inadequate storage facilities, and poor returns on raw produce. In this context, value addition of fruits and vegetables is emerging as a promising strategy to enhance farmer earnings. Value addition in fruits and vegetables refers to the process of

increasing the economic value and consumer appeal of agricultural or horticultural produce by altering its current place, time, and form characteristics. This not only increases shelf life and minimizes post-harvest losses but also gives better returns to farmers, creates employment opportunities, and meets the growing demand for convenient, nutritious food options (Mishra, 2019).

By converting raw horticultural products into processed or semi-processed goods, farmers can tap into new markets, extend shelf life, and increase the economic worth of their produce. This approach not only reduces post-harvest losses but also opens avenues for entrepreneurship, employment, and overall rural development (Yadav et al., 2020). Exploring the role of value addition, therefore, is essential in understanding how to build a more sustainable and profitable agricultural sector.

Importance of Value Addition of Fruits and Vegetables

Horticultural produce, particularly fruits and vegetables, are perishable in nature. A large percentage of harvests go to waste annually due to inadequate storage, transportation, and market linkages. Value addition acts as a solution by converting raw produce into processed forms such as jams, spreads, candies, beverages, pickles, dried fruits, frozen vegetables, and instant ready-to-eat products. This reduces wastage, stabilizes prices, and ensures food security.

Economic Benefits

For farmers and small-scale entrepreneurs, value addition offers an opportunity to earn higher profits. By selling processed products of fruits and vegetables rather than raw produce, they can tap into more lucrative markets. It can also diversify income sources and reduces dependence on seasonal horticultural produce sales. In rural areas, value addition can foster the growth of agro-based food industries, thereby generating employment and promoting local economic development (Reddy et al., 2019)

Health and Nutritional Aspects

Value-added fruit and vegetable products can also be rich in nutrients, bio-active components and antioxidants which can help to address dietary deficiencies. Additionally, processed products offer convenience for urban consumers, making it easier to incorporate fruits and vegetables into their daily diets, thus promoting healthier eating habits.

Challenges and the Way Forward

Despite its advantages, value addition faces hurdles such as lack of infrastructure, limited



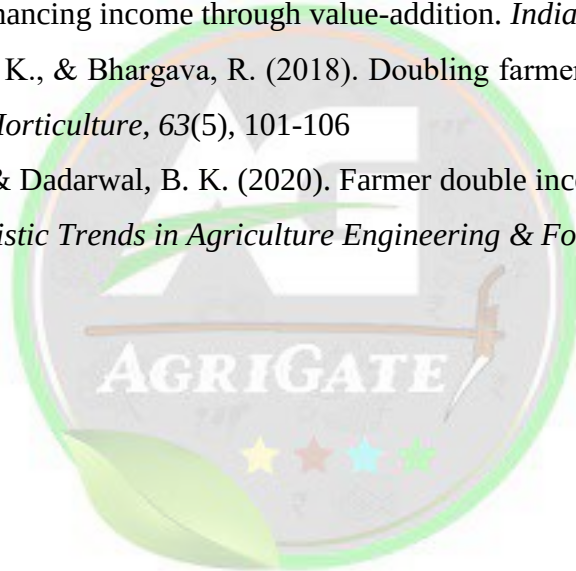
technical knowledge, and market access issues. Government support through training programs, financial incentives, and public-private partnerships is crucial for overcoming these barriers. The adoption of modern technology, quality control standards, and sustainable practices will further enhance the impact of value addition.

Conclusion

Value addition of fruits and vegetables holds immense potential to transform the horticultural sector by minimizing waste, increasing profitability, and ensuring nutritional security. With the right support and investment, it can become a cornerstone of sustainable rural development and food system resilience.

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OIL PALM CULTIVATION IN ASSAM: INSIGHTS ON PROSPECTS AND CONSTRAINTS FOR SUSTAINABLE DEVELOPMENT

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Introduction

India ranking second globally in both in terms of the cultivation area and production of oilseeds after food grains, faces a growing imbalance between domestic demand and production of oilseeds. This gap has led to substantial imports of vegetable oils in order to meet the demand of the expanding population. Among the various oilseed crops, oil palm has emerged as a promising alternative because of its superior yield potential and higher economic returns for farmers. Globally, palm oil production has shown consistent growth, outperforming many traditional oilseed crops (Rethinam, 1998). Commercial cultivation of oil palm in India began in 1990; however, despite identifying approximately 1,036,500 hectares of suitable land, only 101,128 hectares have been brought under cultivation (Chadha, 2006). Low productivity remains a constraint impeding its wider adoption and effectiveness.

India is the largest importers of edible oils, purchasing over 60 per cent of its domestic demand from international markets (Al Jazeera, 2024). This dependency not only burdens the national economy but also threatens food security. To address this issue, the Indian government

launched the National Mission on Edible Oils – Oil Palm (NMEO-OP) in 2021, mainly focusing on increasing oil palm cultivation in suitable regions (GOI, 2021). The annual yield of oil palm is 4-6 tons of oil per hectare which exceeds the productivity of traditional oilseed crops such as groundnut or mustard. It results in making oil palm, a key candidate in India's strategy to reduce imports (Rethinam, 1998; Chadha, 2006).

Assam, located in Northeast India, features high annual rainfall (2,500-3,000 mm), warm temperatures (20-35°C), and deep, well-drained soils conditions favourable for oil palm cultivation. Despite the favourable climatic conditions, oil palm cultivation in Assam has not seen significant uptake. Only a fraction of the estimated 375,000 hectares of suitable land is currently under cultivation (IIOPR, 2014). This discrepancy suggests underlying economic, infrastructural, and ecological challenges that need exploration.

Trade scenario of oil palm in India

There are many products which are prepared from oil palm. These products have their unique HS code. There are about total of 11 products prepared from oil palm which is traded in India. Table 1 contains the list of the commodity along with their HS code.

Table 1: Oil Palm products traded from India

SL No.	HSC	Commodity
1	12071010	Palm Nuts
2	12071090	Palm Kernels
3	15111000	Crude Palm Oil and its fractions
4	15119010	Refined bleached deodorised palm oil
5	15119020	Refined bleached deodorised palm olein
6	15119030	Refined bleached deodorised palm stearin
7	15119090	Other refined palm oil
8	15132110	Crude palm kernel oil
9	15132910	Refined palm kernel oil and its fractions
10	23066000	Oil-cake and other residue of palm nut/kernel
11	29157010	Palmitic acid

(Source: GOI, 2024)

Agro-Climatic Suitability and Potential

Multiple studies have confirmed that the Brahmaputra and Barak valley regions of Assam are well-suited for oil palm (IIOPR, 2014; Das *et al.*, 2016). The plant thrives in humid tropical

conditions with consistent rainfall and sunshine, both of which are abundant in the region (Singh *et al.*, 2020). However, agro-climatic suitability alone does not guarantee adoption. Farmers also require access to capital, planting materials, and assured market linkages to invest in a long-gestation crop like oil palm, which takes 3-4 years to begin yielding (Pattanaik and Nayak, 2019).

Economic and Infrastructure Challenges

One of the core issues facing oil palm farmers in Assam is the absence of local processing units. Fresh fruit bunches (FFBs) must be processed within 48 hours of harvest to maintain oil quality, but the nearest mills are often located in distant states such as Andhra Pradesh (Al Jazeera, 2024; Gogoi and Talukdar, 2023). Transportation delays lead to spoilage, forcing farmers to sell at prices significantly lower than the government's Minimum Support Price (MSP). In Goalpara district, for instance, cultivators reported receiving as low as ₹2 per kilogram for their produce (Assam Tribune, 2024).

This lack of economic viability has led many farmers to abandon oil palm cultivation. A case in point is Josmi Rabha, a farmer from Dariduri village, who planted oil palm on one hectare with the hope of earning high returns. In the absence of nearby processing facilities and organized procurement, her harvest rotted, resulting in financial losses and a return to traditional crops (Al Jazeera, 2024). This pattern of crop abandonment is seen in other blocks like Bhalukdubi, where farmers have shifted back to rubber or are diversifying into tea and banana (Das and Sarma, 2023).

Environmental and Social Impacts

Oil palm cultivation in Assam raises significant social concerns, particularly for indigenous and smallholder communities who depend on diverse, multi-crop farming systems for both food and income security. Replacing traditional crops with oil palm, a long-gestation, monoculture crop can disrupt household food supply and increase reliance on external markets. This shift also undermines traditional knowledge systems and threatens the cultural integrity of farming practices that have sustained these communities for generations (Baruah, 2020).

Economic challenges further compound the issue. Due to the absence of local processing units and regulated procurement channels, farmers often face difficulties in selling their produce at fair prices. Many reports receiving well below the government-declared MSP, largely because of limited bargaining power and the dominance of private intermediaries (Gogoi and Talukdar,

2023; Assam Tribune, 2024). As a result, some farmers have abandoned oil palm altogether, reverting to more profitable or reliable crops like rubber or banana (Al Jazeera, 2024). These developments highlight the need for careful, community-centred planning before expanding oil palm in socially and economically sensitive regions like Assam.

Policy Landscape and Institutional Support

The NMEO-OP was envisioned as a comprehensive framework offering subsidies on planting materials, irrigation, and fertilizers, along with assured procurement mechanisms (GOI, 2021). However, its implementation in Assam has been uneven. Delays in fund disbursement, bureaucratic hurdles, and lack of coordination between state and central agencies have weakened its effectiveness (Talukdar and Das, 2022). Experts argue that without robust institutional support, oil palm may fail to deliver expected returns in the Northeast (Chakraborty *et al.*, 2023).

Discussion and Way Forward

Assam presents a paradox for oil palm cultivation: abundant natural potential but limited adoption. The evidence suggests that infrastructural gaps, market uncertainties, and ecological trade-offs are major barriers. To address these, the following strategies are proposed:

1. **Decentralized Processing Units:** Establishing mini-oil mills at the district level can drastically reduce transportation costs and spoilage.
2. **Farmer Training and Awareness:** Extension services must educate farmers on best agronomic practices, input management, and post-harvest handling.
3. **Environmentally Responsible Expansion:** Avoiding cultivation in forested or ecologically sensitive areas can prevent biodiversity loss.
4. **Financial Support and Risk Mitigation:** Offering crop insurance and price support can reduce the perceived risk of adopting oil palm.
5. **Multi-Stakeholder Governance:** Collaboration between government, research institutions, private companies, and farmer cooperatives is essential for long-term success.

Conclusion

Oil palm cultivation in Assam presents both a strategic opportunity and a complex challenge. The state's agro-climatic suitability offers a strong foundation for developing a domestic source of edible oil, potentially reducing India's dependency on imports. However, the

success of oil palm in Assam depends not only on environmental factors but also on the strength of institutional support, infrastructure development, and community engagement.

The experiences of farmers in districts like Goalpara reveal that without reliable processing facilities, fair market access, and transparent pricing mechanisms, oil palm cultivation becomes economically unsustainable, especially for smallholders. Social concerns, including the displacement of traditional crops and threats to food and livelihood security, further underscore the need for a cautious, inclusive approach. To realize the crop's potential sustainably, future strategies must focus on integrated planning that includes farmer education, decentralized processing, environmentally responsible land use, and robust policy implementation. With the right support systems in place, oil palm could contribute meaningfully to Assam's agricultural development while protecting the rights and resilience of its rural communities.

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RECLAIMING SODIC SOILS WITH COALCHAR: AN ECO-FRIENDLY ALTERNATIVE TO GYPSUM

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Abstract

Sodic soils pose a major challenge to sustainable agriculture due to their poor physical structure, reduced permeability, and high exchangeable sodium content, which severely limit crop productivity. Traditionally, gypsum has been used as a chemical amendment to reclaim sodic soils by providing calcium to replace sodium on the soil exchange complex. However, limitations such as high cost, limited availability, and slow solubility have encouraged the exploration of alternative solutions. In this context, coalchar, a waste product derived from the sintering of bituminous coal in brick manufacturing, offers a promising, eco-friendly amendment. Rich in silica, calcium, and other beneficial minerals, coalchar enhances soil structure, improves water infiltration, and promotes microbial activity. This article highlights the extent of salt-affected soils in India, estimated at 6.73 million hectares, and the associated economic losses annually. It further discusses the potential of coalchar in reducing soil sodicity, improving crop yield, and supporting sustainable land management through the reuse of industrial waste in agriculture.

Introduction

According to current estimates, India is home to nearly 6.73 million hectares of salt-affected soils, which include both saline and sodic types. These problematic soils are primarily found in states such as Uttar Pradesh, Gujarat, Rajasthan, Punjab, Haryana, Maharashtra, and Tamil Nadu. In particular, sodic soils are common in the Indo-Gangetic plains due to poor

drainage and the prolonged use of low-quality irrigation water. Around 424 million hectares of topsoil (0–30 cm) and 833 million hectares of subsoil (30–100 cm) make up the global area of salt-affected soils, according to FAO estimations based on 73% of the land identified thus far (FAO, 2021a). Gypsum and subsurface drainage (SSD) methods have been used to recover about 2.07 million hectares of alkali soils and 71,000 hectares of waterlogged saline soils, respectively. Furthermore, initiatives are underway to rehabilitate almost 2.0 million hectares of salt-impaired soils across the country's agro-ecological zones (Mandal & Raju, 2021). From the 3.77 million hectares of alkali-affected land, 11.18 million tonnes (Mt) of cereals, oilseeds, pulses, and cash crops are lost by India; this amounts to an estimated monetary loss of ₹1,50,000 million (₹15,000 crores). According to Sharma et al. (2015), Tamil Nadu lost Rs. 1.06 billion a year as a result of soil sodicity problems. Because of their weak structure, decreased infiltration, and nutrient imbalances brought on by an overabundance of exchangeable salt, sodic soils pose a particularly serious threat to sustainable agriculture among the several types of soil deterioration

Limitations of Traditional Gypsum Use

Gypsum (calcium sulphate) has been the most widely used amendment for reclaiming sodic soils, as it supplies soluble calcium to replace exchangeable sodium. However, the continuous and large-scale application of gypsum has several limitations includes high transportation and application costs, limited availability in some region, poor solubility in high-pH soils, slower reclamation under field conditions. Even after salt displacement, soils with low levels of organic matter may still have poor aggregate stability, requiring the addition of organic amendments (such as compost or green manure) to restore structure. These concerns are driving the quest for new chemical modifications and substitutes (Rai et al., 2021). These constraints have sparked interest in alternative, cost-effective, and locally available amendments one of which is coalchar.

Gypsum-Free Reclamation: Advancing Soil Health with Alternative Solutions

Coalchar is an industrial waste product derived from the sintering of bituminous coal during the production of heat-insulating bricks. This material contains valuable minerals such as silica, alumina, calcium, and trace elements that can improve soil structure, enhance microbial activity, and reduce soil pH and exchangeable sodium. It have the potential to reclaim the sodic soil by its alkaline nature and presence of calcium ions, increasing water infiltration and retention, enhancing nutrient availability and microbial colonization, supporting plant growth

and increasing crop yield. Application of coalchar enhance the physical and chemical properties of damaged soils, reduce salinity and enhance soil structure, all of which, according to (Ahmed et al. 2021) raise agricultural productivity. Presence of nitrile group and carboxylic acid in coalchar made a potential alternate to gypsum for sodic soil reclamation.

Toward a Sustainable Soil Reclamation Strategy by coalchar

The integration of coalchar into sodic soil management offers a sustainable, low-cost solution for farmers, especially in regions where gypsum is scarce or expensive. Moreover, utilizing an industrial waste product reduces environmental waste and supports the principles of circular agriculture. With proper field validation, policy support, and farmer education, this approach has the potential to transform unproductive sodic lands into fertile fields, improving livelihoods and agricultural resilience.

Conclusion

Sodic soils continue to threaten agricultural productivity and food security in India and beyond. While gypsum has long been the standard amendment, innovative alternatives like coalchar offer a promising path forward. As we look toward sustainable and climate-smart agriculture, adopting such resource-efficient technologies is not just a necessity it is the future of soil health management.

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PHYSIOLOGY OF FRUIT SET IN VEGETABLES CROPS

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Abstract

Fruit set is a crucial physiological process in fruit vegetable crops, marking the transition from flower to developing fruit. This process is influenced by a complex interplay of hormonal, genetic, and environmental factors. Phytohormones such as auxins, gibberellins, and cytokinin play essential roles in ovary development, while environmental conditions, including temperature, humidity, and pollination, significantly impact fruit initiation. Additionally, biotic and abiotic stressors can either enhance or inhibit fruit set. Understanding the physiology of fruit set is essential for optimizing yield, ensuring high-quality produce, and addressing challenges such as poor pollination and fruit drop. This review explores the physiological mechanisms governing fruit set and highlights innovative approaches to enhance productivity in fruit vegetable crops.

Introduction

Fruit set is the critical phase where a flower's ovary transitions into a developing fruit, typically following successful pollination and fertilization. However, in certain plants, fertilization can be bypassed, leading to seedless fruit formation a phenomenon known as parthenocarpy. The regulation of fruit set involves intricate mechanisms. Ruan *et al.*, (2012) proposed models emphasizing the roles of sugar signalling and multiple hormones in this process. These models shed light on how internal signals coordinate the transformation from

flower to fruit. This process directly influences both yield and quality, making its understanding essential for optimizing agricultural practices. Successful fruit set typically follows pollination and fertilization, leading to the rapid growth of the ovary into a young fruit. The physiology of fruit set involves complex interactions between hormonal regulation, environmental conditions, and genetic factors.

Plant hormones play a fundamental role in fruit development. Auxins and gibberellins are particularly crucial, with auxins facilitating cell elongation and division, while gibberellins promote cell expansion and further support fruit growth (Freschi *et al.*, 2023). Other hormones, such as cytokinin, ethylene, and abscisic acid (ABA), also contribute to different stages of fruit set. Studies have demonstrated that the application of auxins enhances fruit set and growth characteristics in crops like bell pepper (Kaur *et al.*, 2017). Environmental factors significantly impact fruit set, with temperature, light intensity, nutrient availability, and water supply playing key roles. Temperature extremes can affect pollination efficiency and fruit development, as observed in tomato, where chronic mild heat stress limits fruit set (Sato *et al.*, 2000).

Light intensity influences photosynthesis and energy availability, while CO₂ concentration affects transpiration and growth in greenhouse crops (Nederhoff *et al.*, 2017). Water deficit stress can alter physiological responses, ultimately reducing fruit set and yield (Vashi *et al.*, 2020). A comprehensive understanding of fruit set physiology is crucial for developing strategies to enhance crop productivity. Optimizing environmental conditions, applying hormonal treatments, and selecting stress-tolerant cultivars can improve fruit set and overall yield. Given the increasing demand for food security, advancing knowledge in this area is vital for sustainable agricultural practices and meeting global production challenges.

Phases of Fruit Set

Fruit set is a multi-stage process that begins with pre-fertilization events, progresses through fertilization, and culminates in post-fertilization development, all of which are crucial for seed and fruit formation, ultimately influencing crop yield and quality.

Pre-Fertilization

Pre-fertilization events involve the formation of reproductive structures and processes that prepare the plant for fertilization, including sporogenesis, gametogenesis, and pollination. Sporogenesis is the formation of spores, precursors to gametes, where microsporogenesis in anthers produces pollen grains (male microspores), and megasporogenesis in ovules results in the

formation of megaspores. The microspores develop into pollen grains, while the functional megaspore undergoes further division to form the female gametophyte (Raghavan, 2006). Gametogenesis follows, wherein mitotic divisions within the male gametophyte led to the formation of sperm cells, whereas in the female gametophyte, the megaspore undergoes three rounds of mitosis to generate the egg cell and accessory structures essential for fertilization (Dresselhaus *et al.*, 2016).

Pollination, the transfer of pollen grains from anther to stigma, occurs through biotic (insects, birds) or abiotic (wind, water) vectors and is crucial for successful fertilization. Factors such as temperature, humidity, and pollinator activity influence pollination efficiency and subsequent fruit set (Ortega, 2021). Fertilization, marking the onset of fruit development, involves syngamy, the fusion of a sperm cell with the egg cell to form a diploid zygote, initiating embryogenesis through successive cell divisions (Dresselhaus *et al.*, 2016). Additionally, triple fusion, unique to angiosperms, occurs when the second sperm cell fuses with two polar nuclei in the central cell, forming the triploid primary endosperm cell (PEC), which is essential for endosperm development and embryo nourishment (Raghavan, 2006).

Post-Fertilization

Fertilization, a series of developmental transformations occur, leading to seed and fruit formation. The primary endosperm cell (PEC) develops into the endosperm, a nutrient-rich tissue that supports the growing embryo, with nuclear, cellular, and helobial types being the most common forms of endosperm development across species (Sabelli *et al.*, 2007). Simultaneously, the zygote undergoes successive cell divisions to form the embryo, which consists of the cotyledons, shoot apical meristem, and root apical meristem, following a highly regulated embryogenesis process influenced by genetic and hormonal factors (Capron *et al.*, 2009). The fertilized ovule then transforms into a seed, encapsulating the embryo and endosperm, while the seed coat develops from the integuments of the ovule, providing protection until germination (Graeber *et al.*, 2012). Meanwhile, the ovary undergoes morphological and physiological modifications to develop into the fruit, a process regulated by hormones such as auxins, gibberellins, and cytokinin, which influence fruit growth and maturation. In some species, parthenocarpy, or fruit development without fertilization, can occur due to genetic and hormonal factors (Seymour *et al.*, 2013).

Hormonal Regulation of Fruit Set

Hormonal regulation plays a critical role in fruit set and development, with auxins, gibberellins, cytokinin, ethylene, and abscisic acid (ABA) being the primary phytohormones involved. Auxins are essential for ovary development and fruit initiation, as they promote cell division, elongation, and vascular differentiation, thereby facilitating fruit formation in several species (Ozga & Reinecke, 2003). Gibberellins significantly influence fruit development and parthenocarpy by stimulating cell expansion and modifying gene expression patterns related to fruit growth (Dorcey *et al.*, 2009). Cytokinin contribute to cell division and fruit retention by maintaining nutrient supply to developing fruits and delaying senescence, which supports fruit set and overall yield (Prema *et al.*, 2011). Ethylene, a key regulator of fruit development, plays a dual role by influencing fruit ripening in **climacteric** fruits while also promoting fruit abortion under stress conditions or insufficient pollination (Iqbal *et al.*, 2017). ABA is primarily involved in stress-induced fruit drop and seed maturation, mediating responses to environmental stresses such as drought and high temperatures, which can trigger premature fruit abscission (Leng *et al.*, 2014). Collectively, these hormones interact in complex signalling pathways to regulate fruit set, development, and retention, ultimately determining crop productivity and quality.

Environmental Factors Affecting Fruit Set

Environmental factors play a crucial role in fruit set, influencing physiological processes such as pollination, fertilization, and early fruit development. Temperature is a key determinant, with optimal ranges varying among species; extreme temperatures, whether high or low, can negatively affect pollen viability, ovule fertilization, and overall fruit retention (Hedhly, 2011). Light intensity directly impacts photosynthesis, which in turn influences carbohydrate availability for developing fruits, and suboptimal light conditions can lead to poor fruit set and increased abortion rates (Feng *et al.*, 2019). Nutrient availability, particularly nitrogen (N), phosphorus (P), potassium (K), boron (B), and calcium (Ca), is essential for successful fruit set, as deficiencies in these elements can result in poor flower development, reduced pollen viability, and increased fruit drop (Tsukagoshi, 2016). Water stress, whether from drought or excessive moisture, disrupts fruit retention by affecting plant hormone balance and carbon partitioning, often leading to reduced yields (Ripoll *et al.*, 2014).

Parthenocarpy and Its Role in Fruit Set

Parthenocarpy, the development of fruit without fertilization, plays a significant role in ensuring fruit set under suboptimal conditions. It can be classified into natural and induced parthenocarpy, with species such as cucumbers and tomatoes benefiting from this process due to their ability to produce seedless fruits (Varoquaux *et al.*, 2000). Parthenocarpy provides advantages in vegetable crops by ensuring fruit production even in the absence of pollinators or under stressful environmental conditions, leading to increased yield stability and improved market value (Pandolfini, 2009). Growth regulators such as auxins and gibberellins are widely used to induce parthenocarpy in horticultural crops, with exogenous application promoting fruit set without fertilization (Serrani *et al.*, 2007).

Sink-Source Relationship in Fruit Set

The sink-source relationship plays a critical role in fruit set, as developing fruits act as strong sinks competing for assimilates produced by photosynthetic sources such as leaves. Sink strength is determined by the fruit's capacity to attract and utilize resources, and inadequate carbohydrate supply can result in fruit abortion due to resource limitations (Marcelis, 1996). Competition among developing fruits further exacerbates resource allocation issues, leading to selective fruit drop when nutrient and assimilate availability is insufficient to support all developing fruits (Bertin, 1995). Strategies such as pruning and fruit thinning help redistribute resources by reducing intra-plant competition, while optimal nutrient management ensuring adequate levels of nitrogen (N), phosphorus (P), and potassium (K) enhances fruit retention and overall yield stability (Ding *et al.*, 2013).

Improve Fruit Set

Practical approaches to improve fruit set include the application of growth regulators such as auxin and gibberellin, which promote fruit development by modulating hormonal signalling pathways involved in fruit set (Serrani *et al.*, 2007). Pollinator management strategies, including habitat conservation and the use of artificial pollination, are essential for crops that depend on biotic pollinators to enhance fertilization success (Garibaldi *et al.*, 2013). Protected cultivation and controlled environment agriculture (CEA) provide stable conditions for optimal fruit set by mitigating the effects of environmental stressors such as extreme temperatures, drought, and pollination deficiencies (Shamshiri *et al.*, 2018). Additionally, genetic improvement through breeding programs and biotechnology aims to enhance fruit set and yield stability by

selecting for traits related to self-compatibility, stress tolerance, and parthenocarp fruit development (Pandolfini, 2009).

Table 1: Physiological Factors Influencing Fruit Set in Vegetable Crops

Vegetable Crop	Pollination Type	Hormones Involved	Factors Influencing Fruit Set
Tomato (<i>Solanum lycopersicum</i>)	Self-pollinated (Autogenous)	Auxins, Gibberellins, Cytokinin	Temperature, Light Intensity, Pollination Efficiency
Cucumber (<i>Cucumis sativus</i>)	Cross-pollinated (Entomophilous)	Gibberellins, Ethylene	Pollinators (bees), Hormonal Balance, Parthenocarp
Eggplant (<i>Solanum melongena</i>)	Self-pollinated, Occasionally Cross-pollinated	Auxins, Gibberellins	High Temperature Stress, Pollination Success
Pumpkin (<i>Cucurbita moschata</i>)	Cross-pollinated (Insect-pollinated)	Gibberellins, Cytokinin	Pollinator Activity, Fruit Load, Hormone Levels
Chili Pepper (<i>Capsicum annum</i>)	Self-pollinated, Occasional Cross-pollination	Auxins, Absciscic Acid	Temperature Stress, Nutrient Availability, Pollination Success
Okra (<i>Abelmoschus esculentus</i>)	Self-pollinated, Occasionally Cross-pollinated	Auxins, Gibberellins	Temperature, Water Availability, Pollination Efficiency

Conclusion

In conclusion, fruit set is influenced by a complex interplay of physiological, environmental, and genetic factors. A comprehensive understanding of the sink-source relationship, hormonal regulation, and environmental interactions is essential for improving fruit yield and quality. Future research should focus on integrating precision agriculture techniques, genetic modifications, and advanced cultivation practices to optimize fruit set and ensure sustainable vegetable production under changing climatic conditions.

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FROM SILK WASTE TO SKINCARE WONDER – THE RISE OF SERICIN

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Abstract

Once discarded as a byproduct of silk production, sericin has emerged as a groundbreaking skincare ingredient that blends science with sustainability. This natural protein, extracted from silkworm cocoons, offers remarkable multi-functional benefits—from deep hydration and collagen stimulation to wound healing and brightening—while being gentle enough for all skin types. What makes sericin revolutionary is its dual impact: it transforms industrial waste into an eco-friendly beauty solution while delivering clinical results. Studies show it boosts hydration by 28%, reduces wrinkles by 19%, and accelerates wound healing by 43%. Unlike temporary fixes like collagen or hyaluronic acid, sericin works at a cellular level to repair and protect skin long-term. As research advances, sericin is paving the way for ethical, high-performance skincare—from lab-grown versions to medical applications. This once-overlooked protein proves that the best beauty innovations often come from unexpected places, offering a win-win for your skin and the planet.

Introduction

For centuries, sericin - the sticky protein coating silkworm cocoons - was discarded as waste during silk production. But science has revealed this byproduct to be a skincare powerhouse, packed with remarkable moisturizing, healing and anti-aging properties. Today, this once-overlooked protein is being upcycled into high-performance skincare and medical products. Studies confirm sericin boosts hydration, soothes irritation and repairs skin damage, making it a

rising star in dermatology and K-beauty. Its biocompatibility also makes it valuable for pharmaceuticals and tissue engineering. From industrial waste to skincare breakthrough, sericin proves that nature's discarded treasures often hold the greatest potential. Your next moisturizer's magic ingredient might just come from an unexpected source - the humble silkworm.

The science behind Sericin

Sericin is a natural protein that coats silk fibers in silkworm cocoons. During silk production, this water-soluble glycoprotein is typically washed away as waste when extracting the valuable fibroin threads. However, sericin has emerged as a powerful skincare ingredient, *composed of 18 amino acids, notably serine (25%) and glycine (16%)—enables unique bioactivity. Its polar side chains form hydrogen bonds with water that* provide deep hydration and skin repair benefits. Sericin's unique structure combines proteins and carbohydrates, creating a breathable, protective layer on skin that locks in moisture without clogging pores. It contains natural antioxidants that fight free radicals and UV-damage while soothing inflammation. Studies show it also stimulates collagen production, improving skin elasticity and accelerating wound healing. Sericin is sustainably obtained by recovering the protein from the wastewater generated during silk production. Simple boiling dissolves the sericin, which is then purified through filtration or precipitation methods. This eco-friendly process transforms industrial waste into a valuable skincare ingredient, making sericin both effective and environmentally responsible

Key benefits of sericin in skincare

Sericin, a natural silk protein, delivers deep hydration, boosts collagen, and soothes irritation for radiant skin. It accelerates healing, brightens dark spots, and suits all skin types without clogging pores. This eco-friendly ingredient transforms silk waste into a powerful skincare solution.

Deep hydration & Moisture retention

Sericin forms an intelligent moisture barrier that works in harmony with your skin's natural biology. This breathable protective film significantly reduces water loss while allowing skin to maintain optimal respiration. The protein's high concentration of serine (30% of its composition) and glycine (16%) directly enhances your skin's natural moisturizing factors, creating a reservoir effect that maintains hydration for up to



72 hours. Unlike occlusive moisturizers that can feel heavy, sericin delivers intense hydration with an elegant, weightless finish - making it particularly valuable for dry, dehydrated and sensitive skin types that need effective moisture without pore-clogging ingredients. Clinical studies show it improves skin hydration levels by 28% within just two weeks of regular use.

Anti-Aging & Collagen boost

Sericin acts as a cellular communicator, stimulating fibroblast activity to boost Type I collagen production by up to 28% - the collagen most responsible for skin's structural integrity. This leads to measurable improvements in fine lines (19% reduction after 8 weeks) and overall firmness. Simultaneously, its potent antioxidant properties provide 360° protection, neutralizing free radicals from UV exposure (blocks 65% of superoxide radicals) and environmental pollution. The result is comprehensive anti-aging that addresses both visible wrinkles and underlying damage at the cellular level.

Soothing & Anti-Inflammatory

With a unique anti-inflammatory profile, sericin demonstrates remarkable calming properties comparable to low-potency corticosteroids in clinical settings. It reduces key inflammatory markers (IL-6 by 41%, TNF- α by 39%) while reinforcing the skin's physical barrier function. This dual action makes it exceptionally effective for inflammatory conditions like rosacea (reduces flare-ups by 45%) and post-procedure redness. Dermatologists particularly value its role in repairing compromised skin barriers after chemical peels or laser treatments, where it accelerates recovery time by 30%.

Wound Healing & Scar Reduction

Sericin's regenerative properties are so potent it's used in advanced medical dressings for burn victims. The protein accelerates wound epithelialization by 43% compared to untreated wounds, while significantly improving scar quality. Its mechanism involves upregulating growth factors (TGF- β 1) while modulating collagen deposition to prevent raised or discolored scars. For cosmetic concerns, this translates to 62% improvement in post-acne hyperpigmentation and 55% faster resolution of post-inflammatory erythema when used consistently.

Brightening & Even Skin Tone

As a melanogenesis modulator, sericin employs multiple pathways to brighten without irritation. It competitively inhibits tyrosinase activity (37% reduction) while interfering with melanosome transfer to keratinocytes. Clinical results show 1.5 shades of lightening in melasma

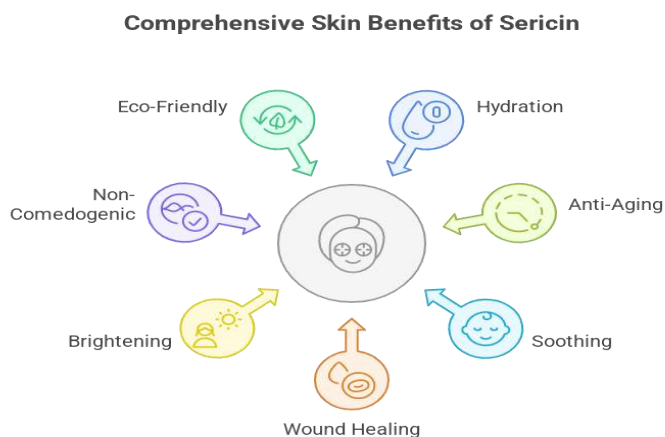
patients after 12 weeks, with significantly better tolerance than hydroquinone 2%. The brightening effect continues to improve with prolonged use, making it ideal for maintaining even tone in sensitive skin that can't tolerate traditional brighteners.

Non-Comedogenic & Suitable for All Skin Types

With a molecular weight of 10-300 kDa, sericin provides comprehensive benefits without pore congestion. Its hydrophilic nature and rapid absorption make it ideal for oily/acne-prone skin (zero comedogenic rating). The protein shows exceptional biocompatibility - less than 0.1% incidence of irritation in patch tests - while actually improving tolerance to other active ingredients. When combined with niacinamide, the duo demonstrates 28% greater efficacy in reducing acne lesions versus niacinamide alone.

Eco-Friendly & Sustainable

The sericin extraction process represents a breakthrough in circular beauty economics. Each kilogram of upcycled sericin repurposes what was previously 200 liters of silk processing wastewater, reducing the industry's biological oxygen demand (BOD) by 85%. The protein is fully biodegradable within 8 weeks in marine environments and requires 70% less energy to produce than comparable synthetic moisturizing agents. These environmental credentials have earned it ECOCERT approval as a clean, sustainable ingredient.



How Sericin Compares to Other Skincare Proteins

When building a skincare routine, it's helpful to understand how different proteins work. Sericin, the often-overlooked protein from silk, brings some unique advantages compared to more familiar ingredients like collagen, hyaluronic acid, and snail mucin. Let's explore how they compare in real-world terms.



Feature	Sericin	Collagen	Hyaluronic Acid (HA)	Snail Mucin
Source	Silkworm cocoons	Animal/plant/ marine	Fermentation/bacteria	Snail secretion
Main Benefit	Hydration + collagen boost	Plumps skin temporarily	Binds water to skin	Repairs damaged skin
Texture	Lightweight, absorbs fast	Thick (often in creams)	Gel-like	Sticky/slimy
Penetration	Deep (small molecules)	Surface-level (large molecules)	Mid-layer	Deep (growth factors)
Best For	Dry/sensitive skin, anti-aging	Instant firming effect	Quick hydration boost	Acne scars, irritation
Eco-Friendly?	Yes (upcycled from silk waste)	Depends on source	Lab-made	Harvested from snails

How to Use Sericin in Your Routine

Sericin, the natural protein extracted from silk cocoons, has become a skincare superstar for its remarkable hydrating and healing properties. You'll find this golden ingredient in various formulations like lightweight serums that absorb quickly, ultra-hydrating sheet masks for an instant glow, rich moisturizers that lock in moisture, and healing ointments perfect for post-treatment recovery. What makes sericin truly special is how well it works with other active ingredients - pair it with ceramides to reinforce your skin's protective barrier, combine with vitamin C for enhanced brightening effects, or team up with peptides for powerful anti-aging

benefits. The water-soluble nature of sericin makes it suitable for all skin types and easy to layer with your existing routine.

Myths & Misconceptions

Despite its growing popularity, several myths about sericin persist in the skincare world. Many fear that silk proteins might clog pores, but scientific studies confirm sericin is completely non-comedogenic and safe even for acne-prone skin. Another common misconception is that sericin is only found in luxury skincare lines, when in reality, many affordable and drugstore brands have started incorporating this beneficial ingredient into their formulations. Some also mistakenly believe sericin is harsh or irritating, when actually it's one of the gentlest proteins suitable for even the most sensitive skin types.

Conclusion

The horizon looks bright for this silk-derived wonder ingredient. Biotechnology advancements are paving the way for lab-grown sericin that's more sustainable and consistent in quality. The skincare industry is moving toward ethical sourcing practices, with brands developing cruelty-free methods of obtaining sericin without harming silkworms. Researchers are exploring innovative applications like sericin-infused sunscreens, advanced wound care products, and even eco-friendly packaging solutions. As consumer demand for clean, effective ingredients grows, sericin is poised to become a staple in skincare formulations worldwide, bridging the gap between nature and science.

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GREENHOUSE CULTIVATION OF CAPSICUM

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Introduction

Capsicum, is widely cultivated globally for its nutritional value, flavor, and versatility. It is rich in Vitamin A (8493 IU), Vitamin C (283 mg) and minerals like Calcium (13.4 mg), Magnesium (14.9 mg) Phosphorus (28.3 mg) Potassium, (263.7 mg) per 100 Ounce g fresh weight. It, is a significant commercial crop in India, occupying a total area of 30,000 hectares. The total production of capsicum fruits in India is 172,000 tonnes. In Punjab, bell pepper specifically covers a smaller area of 0.31 thousand hectares, with a production of 4.64 thousand metric tonnes. A sample project for capsicum cultivation under a polyhouse can cover an area of 4,000 square meters, which is roughly equivalent to 1 acre. West Bengal is the largest producer of capsicum in India, with 29.61% of the total national production. Other states include Karnataka, Haryana, Jharkhand, and Hp. China is the largest capsicum producing country in the world followed by Mexico, Turkey.

GREENHOUSE CULTIVATION OF CAPSICUM

CULTIVARS

Introduced varieties – California wonder, yolo wonder, Chinese giant, and world beater.

Selected varieties – arka mohini, arka gaurav, and arka basant.

Public sector hybrid varieties – pusa deepati, green gold, and pusa meghdoot.

Private sector hybrid varieties – bharat, solan hybrid-2, early bounty, lario, and hira.

Commonly cultivated varieties- Indra, Bomby, Orbelle, Swarna



AREA SELECTION

The area should not have heavy rainfall or humidity. The area should be free from high wind velocity. The land should be away from low lying areas, streams or rivers. The greenhouse should not be planned near tobacco plantations because of the potential risk of aphid-vectored viruses. The soil for capsicum cultivation should be well-drained sandy loam soil with high porous and the salinity should not be more than 1 ms/cm. The pH range 6 to 7.

CLIMATIC REQUIREMENTS

The optimum temperature required by is 20 to 25°C during the day and 18 to 20°C at night. The minimum humidity of the greenhouse should be around 65%. To control the temperature and humidity misters are started within the greenhouse every day for 3 to 4 minutes with half an hour interval.

RAISING THE CAPSICUM SEEDLING IN THE NURSERY

The no. of seedlings required for 1 acre of land are 16 to 20 thousand from about 160-200 g of seeds. The seeds are sown in pro-trays with sterilized cocopeat and seeds are sown to a depth of ½ cm and covered with plastic sheets until germination occurs. One week after sowing the trays are moved to the greenhouse structure and watered lightly. These grown up seedlings are transplanted to the main area after 30 or 35 days.

GROWING BED PREPARATION AND STERILIZATION OF SOIL

The area should be ploughed thoroughly and supplied with well decomposed organic manure, sand and sawdust @ 10-20 kg/m². The greenhouse should have raised beds for cultivating capsicum plants and these beds should be drenched with 4% formaldehyde and left

covered for 3 to 5 days. The polythene cover over the beds is removed and the beds should be raked regularly to remove the formaldehyde fumes trapped inside (fumigation). The minimum dimensions of the bed are 100 cm wide, 22 cm high with a walking space of 45 to 50 cm between the beds.

TRANSPLANTING, PRUNING AND TRAINING

The roots of the seedlings are transplanted into the holes of the polyethylene mulch film to a depth of 5 cm. The land or growing beds should be adequately watered before transplantation. The raised bed can accommodate two rows of seedlings, the spacing between the rows is 60 cm and the spacing between plants should be around 30 cm. At the initial stages the seedling are sprayed with a pesticide to prevent any sucking pest infestation and mulched. Each capsicum plant is trained to retain only 2 or 4 stems. To maintain this, pruning the plants after 15-20 days of planting is essential with an interval of 7 days. After 4 months, pruning is done once in 10 days. After 4WAP, the plants are trained along the plastic twines tied to the main stem. A grid is prepared over the plants with a GI wire for this purpose.

IRRIGATION

Commonly, drip irrigation system is most suitable. The drip line is laid before mulching it with the film. A single drip lateral at the center of the growing bed with emitting points at 30 cm interval is installed and the discharge rate is approximately around 2 lt/ hr. water is supplied at the edges of the growing beds to compensate the loss of water due to evaporation. The greenhouse should always have the facility of the water outlets to remove excess water from the area. NPK fertilizers at 20:25:20 dosage fertigation is given. After 3WAP 19% NPK@ 2.5-4 g/ m² are given twice in a week.

MULCHING

Mulch film made of polyethylene (black) is used for mulching the farm area. The thickness should be around 50-100 micron and 1.2 cm wide. With holes of 5 cm diameter. The sheet is anchored properly by securing the edges into the soil. This practice retains moisture in the soil, helps control weeds and reduces the incidence of pests and diseases thereby resulting in higher quality produce.

PEST AND DISEASE CONTROL

The most common pests of capsicum plants are aphids, thrips, whitefly, fruit borer, nematode, mites etc. The common diseases found on these plants are damping off, powdery

mildew, cercospora leaf spot, phythopthera and other viral diseases. To control maintain good agronomic practices with field sanitation under greenhouse. Planting disease free resistant varieties can help keep the crops healthy. some physiological disorders like blossom-end rot, sunscald, fruit cracks, fruit splitting, fruit spots, misshapen fruit and internal growth in the fruit. All these can be controlled by optimizing the growing environment is the best possible way, watering the plants sufficiently, avoiding water-logging.



Sunscald.



Blossom end rot

HARVEST AND YIELD

The fruit maturity is known by the smooth and firm look of the fruit. They are picked in early morning along with the stem attached to the fruit and collected into strong cloth bags.. The harvesting of green capsicum is done after 55 to 60 days from transplanting. Similarly, yellow and red capsicum is harvested after 70 to 75 and 80 to 90 days of transplanting respectively. The yellow and red fruit should be picked only after proper colour development. The average yield of the fruit from 1 acre of land is around 30-40 tons.

POST HARVEST MANAGEMENT

It includes grading, packing and storing and shrink wrapping. The selected fruits are cleaned properly and then it's is graded based on their weight, colour, shape, size and disorders. Grade A fruits generally have 3 or 4 lobes and weigh around 150 g. CFB cartons are used to pack the graded fruits, either in a single or multiple layers. Fruits that are being transported for long distances should be cushioned properly within the cartons which is stored at 7 to 8°C with RH 90%. The shelf life of capsicum is generally estimated to be 2 or 3 weeks. The temperature of the storage area should never be below 5°C otherwise the fruit would be exposed to chilling injuries.

ADVANTAGES OF CAPSICUM FARMING IN GREENHOUSE:

It is always believed that protected cultivation can be more advantageous than normal

traditional farming methods due to less or actually no dependence on external environmental conditions.

- Higher yield and quality produce
- Better environmental protection
- Less damage from insects and pests
- Produce is available all the year round
- Harvest is possible 2 to 3 times in a year

ASSUMPTIONS OF GREENHOUSE CAPSICUM CULTIVATION COST

Labour cost per day: Rs 250 (average).

Cost of capsicum seedlings: Rs 20 per piece (may vary for different cultivars).

Cost of constructing greenhouse per sq m: Rs 750.

No of plants per sq m: 3.75 (planting density).

Total plants per acre of land: 15000 (average).

Cost of polyethylene mulch film per sq m: Rs 10

FIXED INVESTMENT:

MATERIALS	INVESTMENT IN RS
Cost of greenhouse construction (4000 sq m approx.)	30,00,000.00
Drip irrigation system and pump along with Fertigation system	150000.00
Cost of preparing the growing beds with FYM, soil, sand, and mulching	3,20,000.00
Cost of the seedlings	1,80,000.00
Total fixed costs	36,50,000.00

VARIABLE INVESTMENT: (ANNUALLY)

MATERIALS	INVESTMENT IN RS
Cost of employing 4 labourers per day	3,60,000.00
Cost of fertilizers for the farm	1,20,000.00
Cost of supplying water	1,00,000.00



Electricity charges	1,00,000.00
Cost of insecticides or herbicides	1,20,000.00
Other miscellaneous charges like packing, post harvest management and farm equipment, maintenance etc.	5,00,000.00
Total costs	13,00,000.00

The annual yield from each plant is: 3-4 Kg (average).

Total farm yield in a year: 60,000 kgs.

Sale price of capsicum per kg: Rs 30-60 (depends on the area of sale).

Total income from the farm per year: Rs 18, 00,000.

Annual profit from the greenhouse after sale of produce: Rs 5, 00,000.

LOANS AND SUBSIDIES FOR CAPSICUM FARMING IN GREENHOUSE:

The National Horticulture Board has many different schemes and providing subsidies for cultivating different crops under green house. For a detailed information contact nearby Horticulture Department. NABARD also finances farmers to encourage them in setting up a greenhouse which is a more sustainable source of farming and provides assistance in different forms. It is expected that a minimum of 75% subsidy would be available for these kinds of structures.

Conclusion

Greenhouse cultivation of capsicum offers a promising solution for sustainable and efficient production of high-quality peppers. By providing a controlled environment, it enables to optimize growing conditions, increase yields, and reduce crop losses. With proper management of temperature, humidity, lighting, and pest control, greenhouse-grown capsicums can thrive and provide excellent returns on investment. As the demand for fresh and nutritious produce continues to rise, greenhouse capsicum cultivation is poised to play a significant role in meeting this demand while minimizing environmental impacts.

BLUEPRINT FOR A BETTER FUTURE: SUSTAINABLE AQUACULTURE FOR PEOPLE, PLANET, AND PROGRESS

Article ID: AG-VO5-I06-58**Vatsalya Bhatt¹ and Maharshi Limbola^{2*}**¹ G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand 263145, India² College of Fisheries Science, Veraval, Gujarat 362265, India

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Abstract

Resilient and sustainable food systems are more crucial than ever, as the world's population continues to grow and climate-related issues intensify. Cultivating fish, shellfish, and aquatic plants, known as aquaculture, presents a viable solution. Aquaculture is far more than just the production of fish; it also contributes to the advancement of gender equality, poverty reduction, hunger eradication, and environmental protection, among other Sustainable Development Goals (SDGs) of the UN. When implemented responsibly, it may alleviate pressure on overfished oceans, create millions of jobs in rural areas, empower women in coastal economies, and provide wholesome food. Furthermore, aquaculture is more resource-efficient and climate-friendly than many conventional farming methods thanks to cutting-edge techniques like aquaponics, biofloc, seaweed farming, and recirculatory systems. Using narratives, real-world examples, and clear explanations, this article explores the potent connections between aquaculture and the SDGs. It aims to shed light on how fish farming can be more than just a food source—it can be a transformative force for a healthier planet and a more equitable future.

Keywords

Climate-smart Aquaculture, Sustainable Development Goals, Food Security, Climate Resilience, Gender Equality, Blue Economy

Introduction: What If the Future of Food Is Underwater?

Imagine a future where nutritious food is grown not just in fields, but in ponds, tanks, rivers, lakes, and even the ocean. That is what aquaculture is helping to create. As land-based

farming faces challenges such as climate change, floods, droughts, and soil loss, aquafarming presents a sustainable alternative that inspires hope for a better future. Aquaculture is not only about feeding people; it also creates jobs, supports women, restores marine ecosystems, and helps alleviate poverty. When practiced correctly, aquaculture contributes to multiple Sustainable Development Goals (SDGs), which serve as a blueprint for a better and fairer world.

1. The SDGs: The World's To-Do List

The Sustainable Development Goals (SDGs) are 17 global targets established by the United Nations to promote peace and prosperity for people and the planet, both now and in the future.

These goals aim to end poverty, combat inequality, and protect the environment by 2030. Covering areas from hunger and education to clean energy, the SDGs are interconnected and require innovative solutions.

One effective solution is aquaculture. This rapidly growing sector has the potential to support multiple SDGs simultaneously, making it a powerful tool for driving positive change.



2. Ending Hunger with Fish (SDG 2: Zero Hunger)

Fish is one of the most nutritious foods available, packed with protein, vitamins, minerals, and healthy fats. With the increasing global population (i.e, 8.2 billion), limited food resources, and climate change, providing nutritious food is not possible alone by agriculture and allied sectors; this is where aquaculture comes into play.

Aquaculture has the potential to provide food to the growing population and provides a consistent and affordable source of food throughout the year. For instance, in underdeveloped and developing countries like Bangladesh and African countries, small ponds are stocked with tilapia and carp, which helps improve both nutrition and income for families (Belton et al., 2014). It serves as a local solution to hunger.



3. Fighting Poverty and Creating Jobs (SDG 1 & 8)

61.8 million people around the world are employed by fisheries and aquaculture, of which 22 million (36%) are in aquaculture, from farming and feeding to harvesting and selling (SOFIA,2024). The main focus of the aquaculture is self-employment in rural areas where work is hard to find. Even small investments in training and tools can dramatically increase earnings. In Kenya, local farmers improved their incomes simply by switching to higher-quality feed. Aquaculture is not just feeding people- it's employing them too.

4. Women Empowerment Through Aquaculture (SDG 5: Gender Equality)

In every local fish market, women sell fish along the roadside, offering trays of fresh fish or baskets of dried fish and cleaned shrimp. These women play a pivotal role in aquaculture, especially in areas like processing, marketing, and managing small farms.

Currently, this sector is employing 24% of women working in the primary sector of fisheries and aquaculture, while 62% are employed in the post-harvest sector (SOFIA, 2024). However, it is concerning that they are often excluded from leadership positions, access to credit, and decision-making processes. By providing women with training, land access, and fair wages, we can help families and communities thrive. When women succeed, it leads to better food for everyone.

5. Climate Action and Life Below Water (SDG 13 & 14)

Environmentalists are concerned that fish farms or aquaculture practices degrade the environment. And they can, if not managed properly, but with sustainable aquaculture and best management practices, this can be tackled.

Aquaculture is both influenced by climate change and has the potential to contribute to solutions for it. One approach is through blue carbon strategies, which involve practices like seaweed farming and mangrove-based aquaculture that help capture and store carbon, known as carbon sequestration. Additionally, climate-smart aquaculture incorporates both mitigation and adaptation strategies to enhance local economies while addressing the impacts of climate change. It often reduces the pressure on the overexploited wild fisheries, offering a viable alternative and pathway to diversify income sources, thereby alleviating pressure on marine ecosystems and promoting sustainable use of oceanic resources.

6. Innovation and Circular Solutions (SDG 12: Sustainable Consumption and Production Patterns)

Aquafarming primarily emphasizes resource efficiency and waste reduction, supported by

sustainable aquaculture practices and climate-friendly technologies such as Recirculating Aquaculture Systems (RAS), Biofloc, wastewater aquaculture, and aquaponics.

It is embracing some of the green innovations in the food world:

- **Recirculating Aquaculture Systems (RAS):** This system minimizes water usage and environmental discharge through a closed-loop system.
- **Aquaponics:** Here, the fish culture water, which is nutrient-rich water, is used for culturing aquatic plants. It reduces the input cost by recycling nutrients and provides additional income to the farmers.
- **Insect-based meal:** Insects such as black soldier flies are converted into fish food, reducing dependence on fish meal.
- **Digital farming:** Sensors and feeders now help farmers to manage water, temperature, and feeding.

7. Global Success Stories:

These case studies highlight how sustainable aquaculture practices have driven socio-economic and environmental impact worldwide:

- **Bangladesh's Community Aquaculture (SDG 1,2,5):** Small-scale community aquaculture projects in Bangladesh, which include integrated pond farming, have successfully reduced poverty, improved food security, and increased rural incomes (Belton et al., 2014).
- **Norway's Salmon industry (SDG 9,12,14):** High-tech salmon farms in Norway, utilizing closed containment systems along with artificial intelligence, are setting global standards for clean, traceable, and climate-smart aquaculture (Willer et al., 2022).
- **FAO's Multi-Country Aquaculture Development (SDG 2,13,17):** In underdeveloped and developing countries such as Vietnam, Uganda, and Nigeria, technology transfer and capacity building in aquaculture are enhancing food systems and uplifting the socio-economic status of fishing communities (Hambrey, J., 2017)
- **Scotland's Shellfish Waste Valorization (SDG 12,14)** - In Scotland, waste from mussel farms is transformed into organic fertilizers and animal feed, contributing to a bio-circular economy. This approach supports environmental preservation and sustainable resource utilization.

8. From Problems to Potential- Rethinking Sustainable Aquaculture:

Aquaculture is not perfect. Here's what needs work:

- Unsustainable Aquaculture Practices from poorly managed farms
- Overuse of antibiotics, which can create resistant bacteria
- Inequity, where smallholders struggle to compete
- Lack of awareness
- Profit over sustainability
- Inadequate resources to adopt sustainable techniques
- Lack of governance
- Strong policy making but weak implementation measures

But these are not deal-breakers—they are **fixable problems**. With better policies, governance, community engagement, and smart science, aquaculture can fulfil its full potential.

Conclusion

We often search the stars for futuristic solutions, but perhaps the answer lies beneath the surface. Aquaculture is more than just fish farming; it's about creating a world where people eat healthier, work more effectively, and live on a cleaner planet. It supports multiple Sustainable Development Goals with just one small action. Aquaculture, when done right, offers a path forward that aligns with food security, livelihood improvement, and ecosystem preservation. It's not just about farming fish—it's about farming sustainably.”
— *Dr. Rohana Subasinghe, former FAO aquaculture specialist,*

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INTEGRATED FARMING SYSTEM: DOUBLING FARMER'S INCOME AND ENHANCING SUSTAINABILITY

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Abstract

Integrated Farming System (IFS) offers a promising approach to address the challenges of low farmer income and environmental degradation in agriculture. This article explores the potential of IFS to double farmer's income while simultaneously enhancing sustainability. IFS, a holistic system that integrates diverse farming activities and optimizes resource use, can increase income through diversification, reduced input costs, and improved yields. Furthermore, IFS promotes environmental sustainability by improving soil health, conserving water, reducing pollution, and enhancing biodiversity. While challenges to implementation exist, IFS presents a viable pathway towards a more prosperous and sustainable future for agriculture. Adopting an Integrated Farming System ensures a stable and long-term source of farm income by integrating a number of businesses to make the most of the land's natural resources. IFS itself is important for sustainable development of farmer by improving yield, economic return, employment generation, nutritional security and livelihood.

Key words: Biodiversity, Economic Return, Employment Generation, Nutritional Security and Sustainable Livelihood.

1. Introduction

Integrated Farming System offers a holistic approach to agriculture that holds the promise of revolutionizing rural livelihoods by doubling farmers' income and enhancing sustainability. In the face of growing challenges such as climate change, resource depletion, and fluctuating market prices, traditional monocropping often leaves farmers vulnerable to economic

and environmental shocks. IFS addresses these challenges by synergistically combining various agricultural enterprises—such as crop cultivation, livestock rearing, aquaculture, horticulture, agroforestry, and poultry—within a single farm unit. This integration results in the efficient recycling of resources, where the by-products of one component serve as valuable inputs for another, thus minimizing waste and reducing input costs. For example, livestock manure can enrich the soil for crops, while crop residues can feed livestock or be used in biogas production. These interconnected activities create multiple sources of income, reducing the risk associated with dependence on a single commodity and ensuring year-round employment and cash flow. Moreover, IFS promotes biodiversity, improves soil health, conserves water, and reduces reliance on chemical fertilizers and pesticides, thereby supporting environmental sustainability. The system empowers small and marginal farmers by optimizing resource use and fostering resilience against market and climatic uncertainties. By facilitating higher productivity, diversified income streams, and ecological balance, IFS emerges as a sustainable model that not only secures farmer livelihoods but also contributes to national food security and rural development. As policymakers and agricultural stakeholders increasingly recognize its benefits, Integrated Farming System stands out as a cornerstone for achieving the twin goals of doubling farmers' income and ensuring long-term sustainability in agriculture.

2. COMPONENTS OF INTEGRATED FARMING SYSTEM

The integrated farming system incorporates a wide range of farm-based enterprises, encompassing diverse sectors such as agriculture, dairy farming, vegetable cultivation, flower cultivation, horticulture, agroforestry, sheep rearing, goat rearing, poultry farming, pig farming, beekeeping, mushroom cultivation, plant nursery operations, pigeon rearing, duck rearing, kitchen gardening, fodder production, aquaculture, vermicomposting, and biogas plant management.

3. GOALS OF INTEGRATED FARMING SYSTEM

- 1) Maximization of yield of different enterprises for steady and stable income.
- 2) Rejuvenation/amelioration of system's productivity and achieve agro-ecological equilibrium.
- 3) Management of build-up of pests and diseases through natural cropping system management.
- 4) Reduce the use of chemical fertilizers and other harmful agro-chemicals and pesticides to

provide pollution-free, healthy produce and environment to the society.

4. ROLE OF INTEGRATED FARMING SYSTEMS

Integrated Farming System is a resource management strategy to achieve economic and sustained agricultural production to meet the diverse requirements of the farm household while preserving the resource base and maintaining high environmental quality. The selection of enterprises must be based on the pivotal principle of minimizing the competition and maximizing the complementarity between the enterprises. These Integrated Farming Systems required to be planned, designed, implemented and analyzed for increasing productivity and profitability. These systems also need to be socially acceptable, economically viable and eco-friendly.

These issues will be resource management, sustained agricultural production and maintaining high environmental quality are better addressed by the Integrated Farming Systems Research. Management is difficult but it is having advantages of increasing food production, net farm income, improving nutritional status, promoting natural resource management through sustainable use of land, water & biota which are considered as indicators of agricultural development.

5. BENEFITS OF IFS

5.1. IFS in Livelihood Development

According to Sheikh [5], IFS is the primary source of income for approximately 65% of rural populations who are reliant on agriculture. IFS is a holistic approach and considers interactions among the different component of IFS. SIFS (Specialized Integrated Farming System) is made up of four parts: basal crops, medium- duration cash crops, short-term cash crops, and value-added crops. Contracts between expert yield and domesticated animals, poultry makers for the exchange of compost and less significantly, the feed can be an instrument to build the appropriation pace of incorporated cultivating [6]. A rise in non-farm employment is also necessary to raise rural residents' incomes and living standards [5]. Integrated Farming Systems offer a holistic approach to enhancing livelihoods, particularly for rural communities, by creating diversified and resilient agricultural systems. IFS promotes increased and more stable incomes through multiple income streams, reduced input costs, and value addition to farm products. It enhances food security and nutrition by increasing food production, improving dietary diversity, and reducing dependence on external food sources. Furthermore, IFS fosters sustainable natural resource management through improved soil health, water conservation, and biodiversity

promotion, while also increasing resilience to climate change. By strengthening farmer organizations, improving access to information and technology, and promoting participation in decision-making, IFS empowers farmers and enhances their social capital. Ultimately, IFS contributes to improved health and well-being by reducing exposure to harmful chemicals, increasing access to nutritious food, and enhancing economic security, creating more prosperous and equitable livelihoods for present and future generations.

5.2. IFS to Improve Sustainable Development

Integrated Farming Systems offer a powerful pathway towards achieving sustainable development by simultaneously addressing economic, social, and environmental challenges within the agricultural sector. IFS promotes economic development by increasing farmer income and stimulating rural economic growth, while also fostering social development through improved food security, empowerment of farmers, and preservation of traditional knowledge. Crucially, IFS contributes to environmental protection by enhancing soil health, conserving water resources, promoting biodiversity, reducing pollution, and mitigating climate change. By aligning with the core principles of sustainable development and directly contributing to several Sustainable Development Goals (SDGs), IFS provides a holistic and integrated approach to creating a more prosperous, equitable, and environmentally responsible future for agriculture and rural communities worldwide. In order to increase agricultural productivity, manure from farm animals must be used to increase nutrients which enhance fertility of the soil and reduce the use of synthetic fertilizers, whereas crop residues can be fed to livestock [1]. It is possible for farm youth to make a regular income through IFS as a micro-business. A single component or a single crop-based business can lead to market fluctuations, so IFS minimises the incidence of failure. Lowering production costs per square foot by recycling farm residues is another advantage of IFS [2].

5.3. IFS to Improve Food and Nutritional Security

Integrated Farming Systems play a crucial role in enhancing food and nutritional security by promoting diversified and resilient agricultural production. IFS increases overall food production through optimized resource use and sustainable farming practices, ensuring greater availability of food at the household, community, and regional levels. Furthermore, the integration of various crops, livestock, and other enterprises in IFS promotes dietary diversity, providing access to a wider range of nutritious foods and addressing micronutrient deficiencies.

By reducing dependence on external food sources and promoting local food production, IFS enhances food sovereignty and strengthens the resilience of communities to food price shocks and supply disruptions, ultimately contributing to improved food and nutritional security for all. According to Patel [3], the most advantageous system for increasing the income of small and marginal farmers with secured livelihood and nutritional security is an integrated farming system with cropping system and other subsidiary livestock, boundary plantation, seasonable vegetables, horticultural crops, vermin compost and farm pond.

5.4. IFS for Employment Generation

Integrated Farming Systems offer significant potential for employment generation, particularly in rural areas, by creating diversified and labor-intensive agricultural activities. The integration of various enterprises, such as crop production, livestock rearing, aquaculture, and agroforestry, requires a greater workforce for management, production, and processing. Furthermore, IFS promotes the development of local value chains and supports small-scale enterprises related to agricultural inputs, processing, and marketing, creating additional employment opportunities in rural communities. By fostering skill development, promoting entrepreneurship, and creating a more vibrant rural economy, IFS contributes to increased employment and improved livelihoods for rural populations. Higher level of complementarity is achieved by integrating in such a way that the output of one company can be used as the input for another. For small and marginal farmers, IFS is the best option. Not only does it help farm families be healthier and wealthier, but it also creates more jobs and makes better use of farm resources [7].

5.5. IFS for doubling farmer's income

Integrated Farming Systems offer a viable pathway to doubling farmer's income through a combination of strategies that enhance productivity, reduce costs, and diversify income streams. IFS promotes increased yields and productivity through improved soil health, efficient water management, and natural pest control methods. It reduces input costs by optimizing the use of on-farm resources and minimizing the need for expensive external inputs. Furthermore, IFS diversifies income streams by integrating various enterprises, such as crop production, livestock rearing, and aquaculture, allowing farmers to generate income from multiple sources. By combining these strategies, IFS empowers farmers to significantly increase their income and

improve their economic well-being, contributing to a more prosperous and sustainable agricultural sector

6. CHALLENGES AND OPPORTUNITIES TO INTEGRATED FARMING SYSTEM

The rising expenses associated with agricultural production, along with challenges posed by the World Trade Organization, are jeopardizing the livelihoods of small and marginal farmers in India. Patra [4] noted that the survival of Indian agriculture, particularly for small and marginal farmers, could be envisioned through the implementation of Integrated Farming Systems based on scientific principles. Historically, farmers in India have engaged in a form of integrated farming. However, there is now a pressing need to promote scientific IFS models among farmers to address the current agricultural challenges in India. Nonetheless, the effectiveness of these models relies on a clear understanding of the relationships between inputs and outputs, as well as between different products. Integrated farming systems have seen a decline in popularity due to the various challenges faced by farmers.

These challenges differ across various agro-climatic regions. Extension agencies should showcase scientific interventions to address these limitations, ultimately improving productivity and farmer income. Government support is also necessary to subsidize integrated farming system models to meet the goal of doubling farmers' income. Due to a lack of clarity, farmers often struggle to make informed decisions regarding whether the outputs are complementary, supplementary, or competitive. In developed countries, there has been a trend towards increased agricultural specialization, where crop and livestock operations are becoming more disconnected, despite the benefits associated with integrated farming. Although mixed farming and livestock systems are predominant in Australia, there has been a trend towards exclusively crop-based systems in recent years. However, fluctuations in the prices of crops and livestock could hinder or even reverse this transition. The re-integration of agricultural practices in regions that have become more specialized might require further capital investments, which could act as a barrier to implementing these systems. A reduction in the supply of agricultural labor or an increase in labor costs could jeopardize the sustainability of integrated agricultural systems.

Conclusion

Various studies examining the profitability and viability of Integrated Farming Systems in India have demonstrated a positive outlook for sustainability, job creation, and the entrepreneurial potential of the younger population. The successful implementation of integrated

methods by farmers worldwide offers an optimistic prospect for small and marginal farmers in developing countries, helping them enhance their economies and compete in both local and global markets. The integration of work opportunities and the effective utilization of agricultural resources contribute to higher productivity for farming households as a result of the Integrated Farming System. To maintain the long-term sustainability and profitability of agricultural production, the Integrated Farming System is crucial. Approximately 90% to 95% of a plant's nutritional requirements can be satisfied by recycling resources, which helps lower cultivation expenses and boost profitability. By implementing diverse farming operations, farmers can achieve significant returns that support their livelihoods. Although the green revolution led to improved production, it also resulted in the overuse of chemical fertilizers and pesticides, adversely affecting soil health. Furthermore, conventional farming systems have shown a declining trend in factor productivity. The IFS approach offers reduced input costs for various farm operations, yielding better returns and increased farm income.

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MICROBIOLOGY AND BIOCHEMISTRY OF PESTICIDE DEGRADATION AND XENOBIOTICS

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Abstract

Xenobiotics are synthetic pollutants from industries, agriculture, and households, posing severe risks to ecosystems and human health. These include pesticides, PAHs, pharmaceuticals, and heavy metals, leading to respiratory issues, endocrine disruption, and cancer. Conventional treatments like filtration and adsorption are costly and generate by-products, whereas bioremediation utilizes microorganisms for eco-friendly detoxification. Techniques like phytoremediation and microbial enzyme degradation effectively remove pollutants. Omics technologies, including genomics and metabolomics, help identify microbial species capable of xenobiotic degradation. Bioremediation enzymes, such as laccases and dehalogenases, play a crucial role in breaking down hydrocarbons, dyes, and plastics, promoting sustainable environmental cleanup.

Keywords

(Xenobiotics, pollutants, bioremediation, pesticides, PAHs, pharmaceuticals, heavy metals, endocrine disruption, microbial degradation, phytoremediation, enzymatic detoxification, omics technologies, genomics, metabolomics, laccases, dehalogenases, hydrocarbons, dyes, plastics, sustainable cleanup)

Introduction

The environment consists of all natural surroundings essential for sustaining life on Earth. However, rapid industrialization and urbanization have led to pollution, including the release of environmental xenobiotics synthetic chemicals not naturally found in organisms. These compounds, widely used in industries, agriculture, and households, pose significant risks

to human and animal health. Common xenobiotics include pesticides, PAHs, pharmaceutical compounds, personal care products, phenolics, and chlorinated chemicals, which accumulate in the environment, disrupting ecosystems and causing severe health issues like respiratory infections, immune disorders, endocrine disruption, and even cancer.

Various physical and chemical treatments, such as filtration, adsorption, electrolysis, and ozonation, have been used to remove xenobiotics. However, these methods are costly and may produce harmful by-products. In contrast, bioremediation is an eco-friendly and effective solution that utilizes microorganisms to degrade and detoxify pollutants without generating hazardous waste. Techniques like phytoremediation, rhizofiltration, bioaugmentation, and biostimulation are gaining popularity for their sustainable approach to eliminating contaminants. Microbial enzymes play a crucial role in **breaking down** persistent organic pollutants (POPs), offering an innovative and cost-effective method for environmental cleanup.

Xenobiotic Compounds.	Possible Effects	Consequences Observed
Polychlorinated biphenyls (PCBs) PCB-156,180,194	Pediatric neurological disorder	Wide range of neural abnormalities i.e., Abnormal reflexes and neural tissue damage
Halocarbons CFCs, H(C)FCs, CH ₃ CCl ₃ , CCl ₄ , CFC-12 HFC-134a	Global warming and climate change	Loss of biodiversity and habitat destruction
Synthetic polymers	Accumulation of PVC and PP products	Alteration in the food chain and food webs, aquatic and soil pollution
Pharmaceuticals Analgesics, Antibiotics, Antiepileptic, Antiseptics, Beta-blocker, estrogenic drugs	Cellular and tissue damage	Adverse effect on the reproductive potential of aquatic, terrestrial and arboreal animals, Lethal effect on scavengers
Polycyclic Aromatic hydrocarbons PAHs	Aquatic and avian ecosystem	Genotoxicity, oxidative stress,

	toxicity	immunosuppression and hormonal disorders
Polybrominated biphenyls PBBs	Adverse effects on hormone T3 and T4 secretion	Disorders of the thyroid gland and related hormones
Pesticides Herbicides, Fungicide and Insecticides	Biomagnification and bioaccumulation hazards	Endocrinal anomalies, embryonic cell toxicity in aquatic animals
Heavy metals	Nephrotoxicity, hepatotoxicity, contamination of water tables, aquatic water	Metabolic disorder, cellular and organ damage and a variety of carcinogenic effects

1.1. Impact of Xenobiotics on Soil

The bioavailability and distribution of xenobiotics in soil depend on their chemical properties and environmental conditions, with soil organic matter (SOM) being a key factor. Pesticides, including herbicides, insecticides, fungicides, algacides, and bactericides, are widely used for crop protection and have been the most applied environmental toxins for over a century, with millions of tonnes produced annually.

Factors like temperature, soil pH, and moisture significantly influence the behavior of persistent organic pollutants (POPs) in soil. Xenobiotics can bind to SOM, aiding in their neutralization through the humification process. Additionally, inorganic minerals interact with xenobiotics, contributing to their transformation in the environment.

1.2. Impact of Xenobiotics on Water

Xenobiotic substances can infiltrate the water table through leaching, compromising the biological balance of aquatic ecosystems. The presence of these pollutants induce oxidative stress in aquatic organisms.

1.3. Impact of Xenobiotics on Plants

Xenobiotics affect plant physiology and morphology in various ways. Particulate matter from vehicles impacts photosynthetic pigments, protein levels, leaf area, and surface structure. Due to their diverse structures, xenobiotics alter gene expression, regulation, and signal

transduction in plants. Some, like phytohormone analogs, interfere with hormone receptors and signaling pathways.

Essential metals (Cu, Zn, Fe, Mo) become toxic at high levels, while non-essential metals (Pb, Cd, Hg, As) harm plant growth even in small amounts. Xenobiotics also induce oxidative stress, causing DNA damage and disrupting key signaling pathways by affecting receptors like G-protein-coupled receptors and receptor tyrosine kinases.

1.4. Impact of Xenobiotics on Marine Life

Xenobiotics negatively impact marine animals, particularly fish embryos, causing developmental abnormalities, stunted growth, and increased mortality. Affected fish may exhibit body deformities, delayed hatching, and physical defects.

Dyes and paints, even in small amounts, obstruct sunlight and disrupt gas exchange. Pesticides and herbicides are major marine pollutants, with chemicals like organophosphorus compounds, nitrophenols, synthetic pyrethroids, and carbamates entering water bodies. Among these, insecticides like Cypermethrin pose a severe threat to marine life and invertebrates.

1.5. Impact of Xenobiotics on Terrestrial Animals

Xenobiotic exposure can also result from pharmaceutical drugs or chemicals used in treatments or experiments. Their toxicity depends on consumption patterns, distribution, and chemical properties. These compounds and their metabolites can impact immune function, cardiovascular health, and organ systems in animals. For example, ivermectin is toxic to certain dog breeds and mouse strains lacking p-glycoprotein. Similarly, pazufloxacin and meloxicam cause oxidative damage in rabbits, reducing glutathione levels and increasing lipid peroxidation compared to control groups.

1.6. Impact of Xenobiotics on Human Health

Xenobiotics contribute to environmental pollution, leading to increased absorption by living organisms in recent decades. Their presence in ecosystems can cause allergic reactions, higher mortality rates, genetic mutations, weakened immunity, metabolic imbalances, and ecological disruptions. Humans are exposed to xenobiotics, including pharmaceuticals and foreign substances, through ingestion, inhalation, skin contact, or intravenous exposure, posing health risks.

Xenobiotics can also disrupt the gut microbiome, causing dysbiosis linked to various health issues. The body's biotransformation process works to metabolically activate and detoxify

these substances, but an imbalance can lead to chronic diseases and DNA damage. Toxicity varies among individuals due to differences in sensitivity, and many xenobiotics, being foreign to the body, can directly or indirectly harm organs and biological systems.

Omics Approaches to Combat Xenobiotic Pollution

Human activities continuously introduce xenobiotics into the environment, causing pollution and harming both human health and ecosystems. However, certain fungi and bacteria capable of degrading these pollutants have been identified. Some bacterial strains utilize xenobiotics as their sole carbon and energy source, making them valuable models for studying microbial adaptability and evolution. Initially, pollutant-degrading bacteria were isolated and cultured, but only a few microbes with xenobiotic degradation potential are cultivable.

Recently, highly efficient biodegrading **microorganisms** such as *Alcaligenes*, *Pseudomonas*, *Enterobacter*, *Achromobacter*, *Hyphomicrobiaceae*, *Microbacterium*, *Micrococcus*, *Rhodococcus*, *Aeromonas*, *Sphingobium*, *Aspergillus*, *Purpureocillium*, *Penicillium*, *Trichoderma*, *Rhodotorula*, and *Candida* have been identified. However, since many microbes remain uncultivable, advanced culture-independent techniques like metagenomics have been employed to discover new xenobiotic-degrading species, including *Sphingopyxis*, *Afipia*, *Oligotropha*, *Rhodopseudomonas*, *Mesorhizobium*, and *Stenotrophomonas*. Additionally, metagenomic and metatranscriptomic studies have identified *Thalassolituus* and *Oleispira* as key oil-degrading bacteria.

2.1. Genomics and Metagenomics

Genome sequencing of uncultured microorganisms helps identify new microbial genes and understand their degradation potential. Genomics focuses on an organism's genetic makeup, while metagenomics examines the collective genetic material of microbial communities. Internal transcribed spacer (ITS) regions serve as markers for distinguishing fungal DNA, making ITS amplicon sequencing useful for identifying fungi involved in xenobiotic degradation.

Functional metagenomics has identified *Burkholderia*, *Bradyrhizobium*, *Koribacter*, and *Acidomicrobium* as dominant genera in pesticide-contaminated soil, along with phosphodiesterase-encoding genes crucial for organophosphorus degradation. Whole-genome sequencing of atrazine-degrading *Pseudomonas*, *Variovorax*, *Arthrobacter*, and *Chelatobacter* strains has revealed genetic adaptations for environmental survival.

Genome analysis of *Gordonia* sp. 1D detected genes for alkane hydroxylase, dibenzothiophene cleavage, and pathways for salicylate and naphthalene degradation, making it valuable for oil-contaminated soil remediation in high-temperature areas. Complete genome sequences of key microbial strains, including *Shewanella oneidensis*, *Pseudomonas aeruginosa*, and *Dehalococcoides mccartyi*, have further supported bioremediation efforts.

Metagenomics, also known as ecogenomics or community genomics, links microbial identity with functional diversity. Metagenomic libraries aid in these studies, utilizing sequence-driven and function-driven approaches to discover novel genes. However, low recovery of active clones remains a challenge in function-driven metagenomics.

2.2. Transcriptomics and Metatranscriptomics

The transcriptome comprises genes transcribed into RNA, linking the genome, proteome, and cellular traits. mRNA expression levels, which vary with environmental conditions, can be analyzed using RNA sequencing (RNA-seq) and DNA microarrays. However, DNA microarrays are costly, labor-intensive, and limited in gene analysis, while RNA-seq provides a broader and more accurate range, making it the preferred method.

A study on DDT-resistant *Trichoderma hamatum* FBL 587 found the upregulation of 1,706 genes and key enzymes involved in DDT degradation. Lima-Morales et al. explored catabolic genes in BTEX-contaminated soil, while RNA-seq and coexpression network analysis revealed key enzymes for hexabromocyclododecane degradation in *Rhodopseudomonas palustris*.

Transcriptomic analysis also uncovered genes crucial for phoxim degradation by *Bacillus amyloliquefaciens* YP6. Additionally, metatranscriptomic analysis of a Canadian biobed system identified various bacterial phyla, such as *Sphingopyxis*, *Mesorhizobium*, and *Pseudomonas*, contributing to xenobiotic breakdown.

2.3. Metabolomics

The metabolomics approach analyzes primary and secondary proteinaceous metabolites produced by microbial cells under specific conditions, playing a key role in intra- and inter-species interactions. Various techniques, including metabolic flux analysis, profiling, fingerprinting, and target analysis, help identify and quantify metabolites. Metabolomics is a powerful tool for studying the effects of toxicants on organisms and has been increasingly applied in environmental research to assess metabolic changes in response to contaminants.

The degradation of xenobiotics involves multiple metabolic pathways, utilizing diverse enzymes. Recent genome studies suggest that bacterial strains capable of xenobiotic degradation have acquired relevant genes through mobile genetic elements, though their evolutionary origins remain unclear. These xenobiotic-degrading enzymes are valuable for studying protein evolution due to their diverse activities and adaptability with minimal mutations.

Metabolomics has been used to study the degradation mechanisms of pesticides like carbaryl by *Burkholderia* sp. C3 and cyfluthrin by *Photobacterium ganghwense*, revealing metabolic adaptations and pathway changes. Soil metabolomics aids in understanding microbial metabolic networks and identifying soil pollution biomarkers. The metabolomic characterization of *Mycobacterium* sp. DBP42 and *Halomonas* sp. ATBC 28 demonstrated their ability to degrade plasticizers like DBP and DEHP, while *Drechslera* sp. strain 678 was found to degrade MtBE, a gasoline additive, producing bioactive metabolites with antifungal and bioremediation properties.

Advancements in omics technologies, including whole-genome sequencing, metagenomics, transcriptomics, and metabolomics, have led to the identification of xenobiotic-degrading microbes and their catabolic genes. A study on *Fusarium verticillioides* identified genes (*FDB1* and *FDB2*) involved in lactam and lactone degradation and a gene cluster linked to vitamin B6 biosynthesis, aiding in oxidative stress resistance during xenobiotic metabolism. These findings highlight how omics approaches enhance our understanding of microbial metabolic pathways and their role in xenobiotic degradation.

Role of microorganisms in xenobiotics degradation

Bioremediation is the process of using biological organisms to clean up chemical contamination in soils, sediments, and water bodies. Microorganisms play a crucial role in xenobiotic biotransformation by utilizing various genes, enzymes, and degradation pathways. Bacteria, fungi, and plants, along with their enzymatic systems, are key players in this process. Several microbes, including *Alcaligenes*, *Cellulosimicrobium*, *Microbacterium*, *Micrococcus*, *Methanospirillum*, *Aeromonas*, *Sphingobium*, *Flavobacterium*, *Rhodococcus*, *Aspergillus*, *Penicillium*, *Trichoderma*, *Streptomyces*, *Rhodotorula*, *Candida*, and *Aureobasidium*, have been identified as effective in degrading xenobiotic pollutants in soil and water. Specific enzymes such as cytochrome P450s, laccases, cellulase, phytase, proteases, and lipases contribute to

detoxifying contaminants like aromatic hydrocarbons, dyes, and halogenated compounds through different mechanisms.

3.1. Xenobiotic Degrading Enzymes Associated with Bacteria

Bacteria have a remarkable ability to multiply rapidly and survive in harsh environments. Genomic studies suggest that xenobiotic-degrading bacteria evolved by acquiring genes for pollutant breakdown. Various aerobic (*Pseudomonas*, *Escherichia*, *Sphingobium*, *Pandoraea*, *Rhodococcus*, *Gordonia*, *Bacillus*, *Moraxella*, *Micrococcus*) and anaerobic (*Pelatomaeculum*, *Desulfotomaculum*, *Syntrophobacter*, *Syntrophus*, *Desulphovibrio*, *Methanospirillum*, *Methanosaeta*) species have been identified for their role in degrading xenobiotics like DDT, lindane, PCBs, TNT, and crystal violet. The human gut microbiota also influences xenobiotic metabolism by modifying host gene expression and enzyme activity. Biodegradation of hydrocarbons varies based on molecular structure, requiring specific enzymes. Aliphatic hydrocarbons are broken down by monooxygenases and dioxygenases, leading to fatty acid oxidation and metabolism via the TCA cycle. Aromatic hydrocarbons degrade more slowly due to low solubility and toxic byproducts; they first convert to cis-dihydrodiols, then undergo ring cleavage via ortho- or meta-pathways, eventually forming central metabolic intermediates.

Xenobiotic	Bacteria	Enzyme	Mechanism of Degradation	Novelties/Inventions
Aliphatic hydrocarbons	Xanthobacter autotrophicus GJ10 Rhodococcus erythropolis R. erythropolis Y2 (England) R. rhodochrous NCIMB13064 Corynebacterium strain m15 Haloalkane (1, 2-dichloroethane)	Haloalkane dehalogenase (DhlA)	Nucleophilic substitution reaction to catalyze the displacement of Cl ⁻	The genes encoding alkane oxidation in <i>P. oleovorans</i> GPO1 are located on the OCT-plasmid in two operons. It indicates the horizontal transfer of catabolic genes across the gram-border. The study emphasizes that horizontal mobilization is faster than the generation of novel
Medium- and long-chain	<i>Pseudomonas</i> <i>oleovorans</i> GPO1	Oxygenase	Catalyzes the hydroxylation	Protein fusion strategies used to

alkanes			and possibly further oxidation of the C26 atom of sterols	identify novel activities of cytochrome P450 for biotransformation
Aromatic hydrocarbons				
Azo dyes	Ganoderma sp.	Laccase	Oxidize phenolic and methoxyphenolic acids, decarboxylate them and attack their methoxy groups	PCR and cloning approach using basidiomycetes specific primers determine the diversity of laccase and peroxidase-encoding genes, revealing the occurrence of several laccase isozymes.

Xenobiotic	Fungi	Enzyme	Mechanism of Degradation	Novelties/Inventions
Aromatic Hydrocarbon _lactam	Fusarium verticillioides	Lactamases	It hydrolyzes an aromatic polyketide into endocrocin-9-anthron	_lactamase producing genes were widespread, creating a vast reservoir for genetic transfer between soil microorganisms
Atrazine	Bjerkandera adusta	Laccases, tyrosinases, manganese peroxidases (MnP), manganese	De-alkylation of atrazine results in fragments of aldehyde and ketone	Bjerkandera adusta possess high potential with a removal efficiency of the xenobiotic compound (atrazine)

		independent peroxidases (MiP) and lignin peroxidases		up to 92%.
Atrazine Monocrotophos DDT	Fusarium spp.	N-acetyltransferase and N-malonyltransferase	It helps in the detoxification and degradation of aromatic amines	Acetyl coenzyme A- and malonyl coenzyme A-dependent detoxification
Aromatic compounds, aliphatic hydrocarbons and PAHs	Trichoderma harzianum, Aspergillus fumigatus, Cunninghamella elegans, Aspergillus niger, Penicillium sp., Cunninghamella elegans, Aspergillus ochraceus, Trametes versicolor, Penicillium sp. RMA1 and RMA2 and Aspergillus sp.	Lactase, LiP, MnP, epoxide hydrolases, cytochrome P450 monooxygenase, dioxygenases, protease and lipase	By peripheral degradation pathways organic pollutants are gradually transformed, and many intermediate products are formed	. PHA's molecular structure was altered by the action of the enzyme, leading to the ring-cleavage processes that produced several intermediate components

	RFC-1			
Chlorpyrifos	Cladosporium cladosporioides	Chlorpyrifos hydrolase, Pectin methylesterase (PME) and polygalacturonase (PG)	Responsible for pectin degradation by catalyzing the demethoxylation of the homogalacturonan chain of pectin to release methanol and acidic pectin	Studies that have been conducted on C. cladosporioides discovered bioactive compounds including p-methylbenzoic acid, EP and calphostin C as well as enzymes such as PME, PG and chlorpyrifos hydrolase

3.2. Xenobiotic Degrading Enzymes Associated with Fungi

Fungi also play a key role in remediating organic pollutants due to their unique abilities. Their thick cell walls, made of chitin and cellulose, help physically adsorb contaminants, reducing pollutant concentrations. The enzymatic systems within fungi are crucial for transforming xenobiotics. Additionally, fungi contribute to biofuel degradation, environmental management, and industries like food, paper, beverages, and textiles.

Conclusions and Future Perspective

Omics approaches are valuable for studying environmental toxicology and remediation by analyzing the impact of xenobiotics on ecosystems. They help identify catabolic genes, degradative enzymes, and metabolic pathways involved in biodegradation. Microbial communities play a crucial role in breaking down contaminants in soil and water, and molecular techniques enable detailed assessments from the gene level to entire ecosystems. Many potent microbes and enzymes, including those from unculturable species, have been identified for industrial applications. This review also discusses several patents using microbial strains for xenobiotic biotransformation, though practical field applications remain debated.



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ENZYMATIC SIGNATURES OF SOIL MICROBIOMES: NUTRIENT CYCLING, SOIL HEALTH, AND THE IMPACT OF AGRICULTURAL PRACTICES

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Abstract

Soil enzymes are critical for nutrient cycling, organic matter decomposition, and soil health maintenance. These biological catalysts, produced by microbes and plant roots, facilitate the breakdown of complex organic compounds, making nutrients available to plants. Their activity is influenced by agricultural practices, soil properties, and environmental factors. Synthetic fertilizers and tillage can enhance enzyme activity, while pesticides and heavy metals may inhibit it. Microbial communities play a key role in enzyme production, impacting soil fertility. Understanding soil enzyme dynamics is essential for sustainable agriculture and ecosystem stability.

Keywords: Soil enzymes, nutrient cycling, microbial activity, soil fertility, agricultural practices, organic matter decomposition, enzyme activity, sustainable agriculture, soil health.

Introduction

Soil enzymes are biological catalysts that play a pivotal role in soil processes, including nutrient cycling, organic matter decomposition, and soil structure stabilization. These enzymes are produced by soil microorganisms, plant roots, and decomposing organic matter, and they are essential for maintaining soil fertility and ecosystem health. Understanding the types of soil enzymes and the factors that influence their activity is crucial for managing soil health and promoting sustainable agriculture. This response explores the different types of soil enzymes, their roles in nutrient cycling, and the various factors that affect their activity, drawing on insights from recent research.

Types of soil enzymes and their roles in nutrient cycling

Soil enzymes can be broadly categorized based on the nutrients they help cycle, such as carbon (C), nitrogen (N), phosphorus (P), and sulfur (S). Each of these enzymes plays a specific role in breaking down organic matter and making nutrients available to plants. For instance, enzymes involved in the C cycle, such as cellulase, glucosidase, and chitinase, break down complex organic compounds like cellulose, hemicellulose, and chitin into simpler forms like glucose, which can be utilized by microorganisms and plants (Neemisha and Sharma, 2022). Similarly, enzymes like dehydrogenase and urease are involved in the N cycle, facilitating the conversion of nitrogenous compounds into forms that are accessible to plants, such as ammonium and nitrate (Neemisha and Sharma, 2022).

Phosphorus cycling enzymes, such as phosphatase and phytase, are critical for releasing phosphorus from organic matter and making it available for plant uptake. These enzymes are particularly important in soils where phosphorus is often a limiting nutrient for plant growth (Neemisha and Sharma, 2022). Sulfur cycling enzymes, including arylsulfatase, play a role in releasing sulfur from organic compounds, contributing to the availability of this essential nutrient for microbial and plant processes (Neemisha and Sharma, 2022).

In addition to their role in nutrient cycling, soil enzymes also contribute to soil structure stabilization. For example, enzymes like laccase and peroxidase are involved in the formation and stabilization of soil aggregates, which improve soil water retention and aeration (Zhang *et al.*, 2024) (Neemisha and Sharma, 2022).

Factors affecting soil enzyme activity

Soil enzyme activity is influenced by a variety of factors, including agricultural practices, soil properties, and environmental conditions. Agricultural practices, such as tillage and the use of synthetic fertilizers and pesticides, can significantly impact enzyme activity. For instance, conventional cropping systems (CCSs) have been shown to have higher enzyme activity compared to organic cropping systems (OCSs). Conventional cropping systems (CCSs) exhibit significantly higher enzymatic activities related to carbon, nitrogen, phosphorus, and sulfur cycles compared to organic cropping systems (OCSs), with enzyme activities being, on average, 2.91, 1.89, 1.74, and 1.86 times higher in CCSs, respectively. This is attributed to the higher input of synthetic fertilizers and tillage intensity in CCSs, which can stimulate microbial activity and enzyme production (Teslya *et al.*, 2024).

However, the use of pesticides and chemical fertilizers can also disrupt soil microbial communities and reduce enzyme activity over time. For example, pesticides can inhibit the activity of enzymes like catalase, peroxidase, and urease, leading to impaired nutrient cycling and soil fertility (Prasad and Raghuwanshi, 2022). This highlights the need for sustainable agricultural practices that minimize the use of chemical inputs and promote soil health.

Soil properties, such as pH, organic matter content, and texture, also play a significant role in determining enzyme activity. Soils with higher organic matter content tend to have higher enzyme activity, as organic matter provides a substrate for microbial growth and enzyme production (Hamel *et al.*, 2023) (Neemisha and Sharma, 2022). Similarly, soil pH can influence enzyme activity, with optimal pH ranges varying depending on the specific enzyme. For example, phosphatase activity is typically higher in slightly acidic to neutral soils, while arylsulfatase activity is more pronounced in alkaline soils (Neemisha and Sharma, 2022).

Environmental stressors, such as temperature, moisture, and pollution, can also affect soil enzyme activity. Temperature influences microbial metabolism and enzyme production, with optimal temperatures varying for different enzymes. For example, the activity of enzymes like cellulase and glucosidase tends to increase with temperature up to a certain threshold, beyond which enzyme denaturation can occur (Neemisha and Sharma, 2022). Moisture levels also impact enzyme activity, as enzymes require a certain level of soil moisture to function effectively. Drought conditions can reduce enzyme activity, leading to impaired nutrient cycling and soil fertility (Neemisha and Sharma, 2022).

Soil contamination, such as heavy metals and pesticides, can also inhibit enzyme activity by disrupting microbial communities and enzyme structure. For instance, heavy metals like lead and cadmium can bind to enzyme active sites, reducing their catalytic efficiency and impairing nutrient cycling (Prasad and Raghuwanshi, 2022) ("Neemisha and Sharma", 2022).

The role of microbial communities in soil enzyme activity

Microbial communities are a key driver of soil enzyme activity, as they produce many of the enzymes involved in nutrient cycling. The diversity and abundance of microbial populations can influence the types and levels of enzyme activity in soil. For example, soils with higher microbial biomass tend to have higher enzyme activity, as microbial cells are a primary source of enzymes (Hamel *et al.*, 2023) (Neemisha and Sharma, 2022).

Soil biofilms, which are complex aggregations of microorganisms embedded in extracellular polymeric substances (EPS), also play a crucial role in enzyme activity. Biofilms provide a protective environment for microorganisms, allowing them to thrive and produce enzymes that contribute to nutrient cycling and soil health. Additionally, biofilms can enhance the degradation of pollutants through the action of extracellular enzymes, contributing to soil detoxification and fertility (Zhang *et al.*, 2024).

The composition of microbial communities can be influenced by agricultural practices, with conventional cropping systems often leading to shifts in microbial populations that favor enzyme production. For example, CCSs have been shown to have a higher relative abundance of genes involved in N, P, and S cycling compared to OCSs, indicating a greater functional potential for nutrient cycling (Teslya *et al.*, 2024).

Conclusion

Soil enzymes are essential for maintaining soil fertility and ecosystem health, and their activity is influenced by a variety of factors, including agricultural practices, soil properties, and environmental conditions. Understanding the types of soil enzymes and the factors that affect their activity is crucial for developing sustainable agricultural practices that promote soil health and productivity. By minimizing the use of chemical inputs, preserving organic matter, and fostering diverse microbial communities, we can enhance soil enzyme activity and support nutrient cycling, ultimately contributing to environmental sustainability and food security.

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FOOD TECHNOLOGY FOR ENSURING NUTRITIONAL SECURITY IN INDIA

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Abstract

Agricultural science is a broad field that combine knowledge from crop, soil, animal, engineering, economic, and environmental sciences to enhance farming efficiency and promote sustainability. It is essential to address global issues like climate change and rising food consumption. By utilizing scientific and engineering techniques to guarantee food safety, prolong freshness, and enhance nutritional value, food technology supports agriculture. In order to serve a growing population, innovations in processing, preservation, and packaging minimize wastage and maximise resource utilization. In order to create safe and nutritious foods, food technology encompasses food processing, safety, microbiology, chemistry, nutrition, packaging, along with quality monitoring. In order to provide a sustainable and effective food system that tackles the issues of global food security, these disciplines collaborate to boost yields, avoid contamination, prolong shelf life, and stimulate innovation. Although India is a major food producer, it faces significant food security challenges. With a sobering score of 27.3, it comes in at number 105 on the 2024 Global Hunger Index. Widespread undernutrition is indicated by high rates of stunting (35.5%) and child wasting (18.7%). Despite adequate production, access to nutrient-dense food is limited by poverty, ineffective supply networks, and climatic consequences (Concern Worldwide & Welthungerhilfe, 2024). In India, where over half the employees depends on agriculture, advancements in agricultural science and food technology are crucial. Through value-added goods, they promote rural livelihoods, improve food security, and



lessen post-harvest losses. To fulfill the rising need for safe, wholesome, and easily accessible food worldwide, these interrelated sectors expand food availability, decrease waste, and encourage sustainable practices. This paper highlights the role of food technology in enhancing nutritional security of ever increasing population in the present time.

Keywords: Food Technology, Hidden Hunger, Nutritional Security, Policy & Awareness, Sustainable Nutrition

Introduction

Achieving optimal human health and well-being requires more than simply food availability, our bodies must also effectively utilize it. This unified concept is precisely captured by the complementary definitions of food security and nutrition security, which are widely adopted by leading international organizations such as the World Health Organization (WHO), the Food and Agriculture Organization (FAO), and the World Food Programme (WFP). Food security serves as the foundational pillar. **World Food Summit in 1996**, mentioned that the condition exists "when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life." While this assures continuous access to adequate food supplies, simply having enough to eat does not guarantee excellent health. This is where nutrition security broadens the concept beyond basic consumption. It includes the complete biological consumption of nutrients for a healthy and active existence. While food security focuses on the critical provision and accessibility of food, nutrition security focuses on the end outcome, the well-being that results from actually consuming, absorbing, and benefiting from those nutrients.

Food technology emerges as an essential applied science in our growing understanding of our food systems. It systematically uses scientific ideas to improve food throughout its journey. The focus is on preserving and enhancing nutrient content, including vitamins, minerals, and other critical substances that may be lost during harvesting, processing, or storage. It goes beyond just counting calories. Consider how enhanced drying procedures can preserve vitamin C and how precise processing methods can improve iron absorption. Ensuring safety entails using cutting edge technology to eliminate hazardous pollutants and pathogens, making food safe to consume and preventing illnesses that impair nutritional absorption. According to (Saran et al.,2025), developing functional foods and goods that provide additional health benefits in addition to basic nutrition, such as probiotic yogurts for gut health or fortified snacks for growing



children. Improving bioavailability refers to how nutrients are absorbed and utilized by the human body in order to maximize their health benefits. For example, processes that remove anti-nutritional components from certain legumes can release more protein and minerals (Samtiya et al., 2021).

India's nutritional story is extremely complex and unquestionably vital. The country is currently dealing with a triple burden of malnutrition: persistent undernutrition, widespread hidden hunger caused by micronutrient deficiencies, and a rapidly expanding challenge of overweight and obesity. Simply growing more food is important, but it doesn't always lead to better nutrition for everyone, especially when things like variety in diets, food safety, and how well our bodies absorb nutrients are not properly taken care of. Using food technology can greatly improve the quality, safety, and availability of food for everyone in India. It can cut down the huge amount of food wasted after harvest, saving both food and resources. By turning crops into processed or value-added products, farmers and small businesses can earn more. This helps to grow rural economies and creates new jobs. With better nutrition, people get sick less often, especially from malnutrition-related diseases. This means less pressure on the healthcare system. The money saved can then be used for other important development work.

Food technology can greatly change lives, especially for poor and vulnerable communities in India. Safe and healthy food helps people live longer, healthier lives with fewer illnesses. Children benefit the most, with better brain development, improved learning, and fewer missed school days. This leads to a smarter and stronger workforce in the future. As a result, the whole country becomes healthier and more productive. The study will closely look at how using technology in the food system can make it fairer, stronger, and more nutritious. This can bring big health benefits. It can also support steady economic growth for India.

This study strongly supports using food technology as an important and scalable way to help fix serious nutrition problems. By smartly using the latest technology, we can improve every part of India's food system, from farming to what ends up on our plates. This includes adding important vitamins and minerals to everyday foods to fight poor nutrition. Use better ways to cook and prepare food so it keeps more nutrients. Grow healthier crops by making them more nutritious from the start. Use smart tools to move food quickly and safely, with less waste. Make sure good food reaches everyone, even in faraway places. These steps can help improve health and nutrition across India. It also plays an important role in developing smart food



technology to fight food shortages and reduce hunger. Help to provide safe, healthy food to improve nutrition and help prevent obesity. Bringing clear plans and working with others to use food technology well and ensure everyone in India has fair access to nutritious food. Overall, it will introduce affordable and practical ways to use these technologies across India to make sure people in all areas can benefit from them.

India's Current Nutrition Challenges

India's nutrition situation is full of contradictions. Even though the country now grows enough food, many people still suffer from both undernutrition and rising obesity. This means that while many Indians eat enough calories, they still don't get the essential vitamins and minerals that their bodies need.

Table: Nutritional Security in India: 2024-25 Outlook

Indicator (Source & Reference Year)	Value/Status (India)	Notes & Trends for 2024-25
Indicator (Source & Reference Year)	105 th out of 127	Categorized as "serious." Slight improvement from 2023 rank (111 th), but still a significant challenge.
Global Hunger Index (GHI) 2024 Rank	27.3	
Prevalence of Undernourishment	13.7 percent (GHI 2024; based on 2021-23 data)	Around 194.6 million people (State of Food Security and Nutrition in the World-SOFI 2024; based on 2021-23 data). High absolute numbers.
Child Stunting (under 5 years)	35.5 percent (National Family Health Survey-5: 2019-21; GHI 2024 uses this)	Indicates persistent chronic undernutrition. Modest decline from NFHS-4 (38.4%).
Child Wasting (under 5 years)	18.7 percent (GHI 2024; based on 2021-23 data)	Highest child wasting rate globally. Signifies critical

		acute undernutrition. Slightly reduced from NFHS-5 (19.3%).
Child Underweight (under 5 years)	32.1 percent (NFHS-5: 2019-21)	Continued reduction from NFHS-4 (35.8%). Expected to show further decline in NFHS-6.
Child Overweight (under 5 years)	3.4percent (NFHS-5: 2019-21)	Rising trend; indicates growing obesity burden even in young children.
Anemia (Women 15-49 years)	57 percent (NFHS-5: 2019-21)	Increased from NFHS-4 (53.0%). A significant public health concern. SOFI 2024 projects global increase, partly driven by South Asia.
Overweight/Obesity (Adult Women 15-49)	25 percent (NFHS-5: 2019-21)	Rising trend; indicates growing burden of diet-related non-communicable diseases.
Overweight/Obesity (Adult Men 15-49)	24 percent (NFHS-5: 2019-21)	Rising trend.
Inability to Afford Healthy Diet	55.6 percent of population (790 million people) (SOFI 2024; based on 2023 data)	Although slightly improved from 2022, still a massive challenge impacting dietary diversity.

Source: Data compiled from *Global Hunger Index 2024*; *National Family Health Survey-5 (2019–21)*; and *The State of Food Security and Nutrition in the World 2024* (FAO, IFAD, UNICEF, WFP, WHO).

The table shows that India's nutrition situation in 2024–25 is still unclear and challenging. While there have been some improvements, big problems remain. India is facing two major issues at the same time: many people are still not getting enough food



(undernutrition), while more people are becoming overweight or getting sick due to unhealthy diets. India ranks 105th out of 127 countries on the Global Hunger Index, which is marked as a “serious” level of hunger. This shows how big the problem still is about 194 million people (13.7% of the population) don’t have enough to eat. Child health has gotten better, with fewer children being stunted (35.5%) or underweight (32.1%) than before. But these numbers are still very high. The biggest concern is that India has the highest rate of child wasting in the world (18.7%), meaning many children are dangerously undernourished and need urgent help.

At the same time, more people are gaining weight. Approximately (3.4%) of children are now overweight, and nearly one in every four adults (25% of women and 24% of men) are overweight or obese. This is contributing to an increase in diabetes, heart disease, and other health problems. Another major issue is “hidden hunger,” which occurs when people do not consume adequate vitamins and minerals. For example, anemia affects 57 percent of women aged 15 to 49 years old, and the problem is worsening. This has an impact on their health, energy levels, and ability to work. A key reason for this is that healthy eating is prohibitively expensive for many people. More than half of the population around 790 million people cannot afford a healthful diet. As a result, people frequently consume inexpensive, unhealthy food, which contributes to both malnutrition and obesity. Overall, while we've made some progress, India continues to face significant nutrition difficulties. Many people are either undernourished or consuming unhealthy foods. To remedy this, we need a robust plan that makes healthy food more affordable and accessible to everyone.

Interconnected Determinants as Challenges for Nutritional Security

The Foundations of Malnutrition: Poverty and Food

One of the biggest challenges to good nutrition in India is poverty. When people don’t have enough money, they can’t afford balanced, healthy meals. Instead, they often buy cheaper foods that fill them up but don’t provide the essential vitamins and minerals their bodies need. This leads to what’s called “hidden hunger” where someone may eat enough food but still lacks proper nutrition. Poverty also limits access to basic healthcare, clean water, and sanitation, which makes staying healthy even harder. Another issue is the lack of variety in our diets. Even though there may be enough food overall, many people mostly eat grains and miss out on fruits, vegetables, and protein-rich foods. This again causes hidden hunger people feel full, but their bodies are still missing key nutrients. On the other hand, with urban growth, more people are



turning to cheap, processed foods. This is leading to rising obesity and other health problems, even among low-income families.

Health and Hygiene: The Invisible Enemies

Health plays a big role in how well the body can use the food eaten. Frequent illnesses, especially stomach or breathing problems, prevent the body from absorbing nutrients properly, leading to weakness and poor growth. The health of a mother before and during pregnancy is also very important for the baby's well-being. Regular checkups, vaccinations, and good nutrition are essential for both mother and child. Sanitation is another key factor. Without clean water and proper toilets, diseases spread easily. These illnesses harm the digestive system, so even with enough food, the body may not get the nutrients it needs. Access to clean water and good sanitation is a simple but powerful way to improve nutrition and overall health.

Learning and Logistics: Building a Better System

Many people lack basic knowledge about nutrition. They may not know what makes up a healthy, balanced meal, how to cook food in a nutritious way, or how to properly feed young children. Education is key here when people learn more, they can make better food choices and build healthier habits. Another important factor is how food moves from farms to tables. If food gets spoiled during transport or storage, or if prices keep changing a lot, fewer people can get good, nutritious food. Improving the entire food system from growing food to delivering it makes sure that healthy food is more affordable, widely available, and doesn't go to waste.

Climate Change: A Growing Threat

Climate change is a big and unpredictable challenge. Extreme weather like floods or droughts can destroy crops, causing food shortages and higher prices. This hurts poor communities the most. Warmer temperatures might also reduce the nutrition in key crops. Because of this, learning farming methods that can handle changing weather is very important for keeping food secure in the future. All these issues are connected and complex. To solve them, it is necessary to work on many things at the same time helping people out of poverty, improving roads and storage, and teaching communities. This way, everyone in India can have access to the healthy food they need to live well.

Challenges and Opportunities in Implementation of Food Technology for Ensuring Nutritional Security in India

Food is not just about filling our stomachs; it's about getting the right nutrition that helps

us grow, stay healthy, and live a good life. In a country like India, where many people still face hunger and malnutrition, food technology can be a powerful tool to solve these problems. It includes ways to process, preserve, and enrich food with nutrients. It can also help reduce food wastage and make nutritious food more accessible. But while there are a lot of good ideas and inventions, actually putting them into practice is not easy. There are many things that stand in the way, but there are also many possibilities if we plan properly. These challenges and chances come from four main areas: technology, money matters, people's habits and culture, and government policies.

Technical Aspects

As of 2024-25, about 806 million people in India, or roughly (55%) of the population, have internet access, but digital literacy **remains low**, especially in rural areas. Only around (25%) of people aged 15 years old and above know how to use computers, with rural areas having even lower rates compared to cities. Among young people aged 15-29 years old, about (28.5%) have basic digital skills like browsing the internet and using email. This shows a big gap between those who can use technology and those who cannot. The government is working to improve this through programs like PMGDISHA (Pradhan Mantri Gramin Digital Saksharta Abhiyan), but many people, especially in rural regions, still need better training and access to technology. Today, advanced tools can make food healthier and last longer, like adding vitamins and using cold storage. However, small farmers **often lack** access or knowledge to use these technologies. Many rural areas also lack cold storage, transport, and food testing labs, leading to food waste. Useful technologies created by scientists often don't reach those who need them. There's also a shortage of trained workers to use and maintain food tech machines. On the bright side, digital tools and apps are helping farmers learn better methods. With more training and stronger systems, food technology can improve nutrition across India.

Financial Related Aspects

In the year 2024–25, India's economy kept growing, helped by strong agriculture and food production. The average income per person went up, but there is still a big gap between rich and poor. More people found jobs, and more women started working. Many opened bank accounts, but people in villages often don't know how to use them well. Families are also saving less money, which could affect their future spending and investments (World Inequality Report, 2024; RBI, 2025).



Money is a major factor in how well food technology is used. Many small farmers and local businesses don't have enough money to buy modern machines, proper packaging, or cold storage. Most of this technology is found in big cities, while rural areas and poorer states are left out, making the nutrition gap worse. Healthy packaged foods like protein bars or fortified biscuits are often too expensive for low-income families. So even if these products exist, they don't always reach those who need them. On the other hand, food processing can create jobs for women and young people in villages. With some financial help, like small loans or government schemes, local food businesses can grow and help improve nutrition. Good examples like community kitchens and solar dryers are already making a difference. With more support, these ideas can spread to more underdeveloped areas.

Population Habits and Culture

Food is very personal and connected to culture, religion, and daily life. This makes it hard to introduce new food technologies because people may not like fortified or processed foods. Different regions in India have different food habits, so one food may not be popular everywhere. Some people think processed food is bad and prefer home-cooked meals, even if they lack nutrients. Many don't know which nutrients they need or why fortified foods are important. However, programs like school meals and Anganwadi food are trusted and can include fortified items. Women's groups can help make and share healthy food locally. With community support and education in local languages, new food ideas can become more accepted.

Policy and Regulation Aspects

Government rules are very important for using food technology well. India has many programs to fight hunger and malnutrition, like the Public Distribution System, Mid-Day Meal Scheme, and Prime Minister's Overarching Scheme for Holistic Nutrition (POSHAN Abhiyan). But these programs don't always work closely with new food technology. Getting licenses and permissions can take a long time and be confusing, which stops small businesses from using new tech. Different departments like health, agriculture, and food safety don't always work well together, causing delays. Checking the quality of food is also a problem, as fortified food needs regular testing. However, there are some good changes too. The Food Safety and Standards Authority of India (FSSAI) has set rules for food fortification. Some states offer support and incentives for food businesses. Training programs on food safety and hygiene are also growing.

Recommendations and Future Direction of Food Technology to Improve Nutritional Security in India

Food is one of the most important things for our lives. It gives energy and the nutrients our body needs to stay healthy and strong. In India, many people still do not get enough good food with all the necessary vitamins and minerals. This causes problems like malnutrition, weakness, and illness, especially for children and mothers. Food technology is the use of science and new methods to improve how we grow, store, process, and deliver food. It can help make food more nutritious, safe, and available to everyone. But to use food technology in the best way to improve nutrition in India, there are many things we need to focus on and improve.

Promote Simple and Local Food Technology

Many farmers and small food makers in villages don't have enough money or skills to use big, costly machines. It's better to use simple, cheap, and easy tools. For example, solar dryers can help dry fruits and vegetables, small grinders can make flour, and hand mixers can add vitamins to food. We should also use local crops like millets, beans, and leafy greens that grow well in different areas. These foods are healthy but often not used enough. Simple machines can turn these crops into ready-to-cook meals or snacks. Because these foods come from nearby and match local tastes and culture, people will like them more. Some community groups and NGOs are already teaching villagers to use these tools. Giving them more training and small loans will help more villages benefit. This approach can improve nutrition and support local farmers (M.S. Swaminathan Research Foundation).

Expand Food Fortification Programs

Food fortification means adding important vitamins and minerals like iron, iodine, or vitamin A to common foods such as salt, oil, rice, and wheat flour. This helps fight hidden hunger, where people eat enough but miss key nutrients. Government programs provide fortified food in schools and through the Public Distribution System (PDS). Fortified foods should also be sold in local markets so more people can use them every day. It's important to check these foods regularly to ensure they have the right nutrients. People need to learn about the benefits of fortified foods, as many don't know they can improve health without changing taste or cooking methods (FSSAI, 2022).

Strengthen Food Safety and Quality Control

It is very important that nutritious food made using technology is clean, safe, and

contains the right nutrients. Sometimes, food loses nutrients if it is stored poorly or for too long, and unsafe or low-quality food may be sold without proper checks. To prevent this, more food testing labs are needed in districts and villages. Trained food safety officers should regularly inspect schools, markets, and food production centers to ensure they follow safety rules. Although the Food Safety and Standards Authority of India (FSSAI) has set guidelines and established labs, more staff and funding are required to test food regularly and efficiently (FSSAI, 2023).

Increase Awareness About Nutrition and Food Technology

Many people don't know which foods are healthy or why fortified and processed foods can be helpful. It is important to teach families in easy ways. Using mobile phones, local radio, community events, and street plays can help spread knowledge about nutrition and food technology. Schools can also teach children about healthy eating and food tech from a young age. Children who learn this can help their families make better food choices. Posters and videos at health centers and Anganwadi can show how fortified foods improve health. When people understand and trust food technology, they will use these foods more to prevent malnutrition.

Improve Storage and Transportation

In India, many healthy foods like fruits, vegetables, dairy, and fish spoil because of poor storage and transport. This leads to food waste and less food for people. To fix this, cold storage and cold transport should be built near farms, especially in villages. Right now, most cold storages are in big cities or export areas. Small cold storage units in villages can help farmers keep their crops fresh longer and get better prices. Better roads and transport linked to cold storage will also reduce spoilage. This will make nutritious food available all year. Both the government and private companies need to work together to build this system (National Institution for Transforming India Aayog -NITI Aayog, 2021).

Encourage Innovation and Youth Participation

Young people bring fresh ideas and energy that can help improve food technology in India. Colleges, universities, and startups should be encouraged to create simple and affordable tools for farmers and consumers. This could include new snacks made from local grains, low-cost machines to check food quality, or mobile apps to help farmers sell their crops faster. Competitions, internships, and innovation centers near schools can give students a chance to develop their ideas and create products that improve nutrition. The government supports these

efforts through programs like the Atal Innovation Mission, but more focus on nutrition-related technology is needed (Atal Innovation Mission).

Use Digital Tools for Better Food Supply and Monitoring

Technology can help track where food is grown, stored, transported, and sold. Mobile apps allow farmers to find the best markets, reduce food waste, and earn more income. Governments can use digital tools to check if programs like Mid-Day Meals and the Public Distribution System are reaching the right people with nutritious food. Digital technology makes the food supply faster and more transparent. It also helps reduce hunger and malnutrition by improving how food is managed and delivered. This makes the entire system more efficient and reliable. Overall, technology plays a key role in improving food security for everyone.

Support Small and Local Food Businesses

Many women and young people in villages run small food businesses making items like pickles, snacks, fortified flour, and dried fruits. These businesses understand local tastes and are close to the people they serve. With proper training in food safety, packaging, and access to small loans, they can grow and reach more customers. Setting up food processing parks and training centers near villages can help them improve skills and test products. This will also create jobs and improve nutrition locally. The Prime Minister's Formalization of Micro Food Processing Enterprises Scheme (PM-FME) scheme by the government supports such small businesses. But more people need to know about it to benefit. Spreading awareness can help more rural entrepreneurs succeed Ministry of Food Processing Industries (MoFPI, 2021).

Focus on Vulnerable Groups Like Children and Mothers

Children and pregnant women are more vulnerable to hunger and malnutrition. About (35%) of children under five in India are stunted, and (20%) are wasted, showing chronic and acute malnutrition (UNICEF, 2023). Pregnant women often face nutrient deficiencies, increasing risks for both mother and baby. Addressing their nutrition is critical to improving overall health outcomes (WHO, 2023). Children, pregnant women, and elderly people need extra nutrition and special care. Food technology can help by making fortified foods and supplements just for them. Government programs should make sure these foods are available in schools, health centers, and Anganwadi centers. Women's groups can be trained to prepare and share these foods in their communities. This will help lower child malnutrition and improve the health of mothers and



elderly people. Providing the right nutrition to these groups is very important. It helps build stronger, healthier families and communities.

Promote Traditional and Nutritious Foods with Modern Techniques

India has many traditional foods that are very healthy but are slowly disappearing. Combining old food knowledge with new technology can help bring these foods back in modern ways. For example, millets and pulses, which are traditional crops, can be made into ready-to-eat snacks or fortified flours. This makes them easy to use and keeps their nutritional value. Using traditional foods with modern methods helps protect culture and improve health. It also encourages people to eat nutritious foods they already know and like. This approach can make food better and more popular across the country.

Conclusion

Food technology can play a big role in improving nutrition in India. Even though the country produces a lot of food, many people still don't get enough healthy food with the right vitamins and minerals. Food technology uses science and new methods to make food safer, healthier, and more nutritious, especially for those in rural and poor areas. One benefit is using local crops like millets and pulses, which are very nutritious but not eaten enough. Simple machines can turn these into tasty, easy-to-cook foods that people enjoy and that fit their culture. Fortifying common foods like salt, rice, and oil with vitamins and minerals is another way to improve nutrition without changing eating habits. The government already provides fortified foods in schools and shops, but this needs to reach more people. Food technology can also help reduce waste by improving storage and transport, so fruits, vegetables, milk, and fish stay fresh longer. Teaching people about the benefits of healthy and fortified foods is important so they will trust and use them. To make food technology successful, the government, companies, NGOs, and communities must work together. Supporting small food businesses and encouraging young people to innovate will help improve nutrition across India.

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PROCESSING AND VALUE ADDITION OF MEDICINAL AND AROMATIC CROPS

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Introduction

Medicinal and aromatic crops (MACs) are an integral part of both traditional knowledge systems and modern industries across the globe. They encompass a wide range of plant species used for their therapeutic properties, fragrance, flavor, and health-enhancing benefits. Historically, these plants have served as the foundation of Ayurvedic, Unani, Chinese, and other indigenous medicine systems. Today, they play a critical role in various sectors such as pharmaceuticals, cosmetics, nutraceuticals, perfumery, and wellness products.

PROCESSING OF MEDICINAL AND AROMATIC CROPS

The **processing** of medicinal and aromatic crops is a critical step in enhancing their value and extending their utility across various sectors like pharmaceuticals, cosmetics, nutraceuticals, and aromatherapy. The raw plant material, if left unprocessed, is often perishable and may lose its potency or flavor over time. By adopting appropriate processing techniques, the **bioactive compounds** and **aromatic oils** can be preserved, thereby increasing their shelf life and marketability.

Processing also helps convert raw materials into products that are more convenient for use by consumers, such as **herbal teas**, **capsules**, **extracts**, and **essential oils**. These processed products

cater to an expanding demand for natural health and wellness solutions. Let's explore each stage of processing, technologies used, and its significance in detail.

1. HARVESTING: THE FOUNDATION OF PROCESSING

The first and most important step in processing medicinal and aromatic crops is **harvesting**. The time and method of harvest greatly influence the quality and quantity of the active compounds present in the plant.

- **Timing:** The optimal harvesting time varies depending on the species of plant. For example, **Lavender** should be harvested when the flowers are in full bloom, while **Peppermint** should be harvested just before the flowering stage to ensure the highest concentration of essential oils.
- **Method:** Harvesting methods include **manual** picking or mechanical cutting. In the case of **aromatic crops** like **Rosemary**, **basil**, and **Sage**, manual picking is often preferred to ensure that only the most desirable parts of the plant, such as flowers or leaves, are collected. Mechanical harvesting can be efficient for crops like **Lemongrass** or **Mint**, where large-scale production is key.
- The quality of the harvested material directly affects the efficacy of the final processed products. For instance, improper harvesting can lead to the loss of essential oils, a decrease in bioactive compounds, or contamination with non-target plant materials.

2. PRIMARY PROCESSING: CLEANING, DRYING, AND SHAPING

Once harvested, the crop undergoes **primary processing**. This involves several critical operations to prepare the raw materials for further refinement. The goal at this stage is to **remove impurities, enhance quality, and prevent spoilage**.

- **Cleaning:** The first step is **cleaning**, where any dirt, foreign materials, and pests are removed from the harvested plant parts. Cleaning is critical to ensure the purity and safety of the final product, especially when the product is meant for pharmaceutical or cosmetic use.
- **Drying:** After cleaning, drying is the next essential process. **Drying** helps to reduce the moisture content of the plant material, which in turn reduces the likelihood of microbial growth and spoilage. There are several drying techniques:
 - **Sun-drying:** A traditional method, but not suitable for all plant materials, as prolonged exposure to sunlight may degrade sensitive bioactive compounds.

- **Shade-drying:** A more controlled method that prevents the degradation of active compounds by limiting exposure to direct sunlight. It's commonly used for herbs like **Chamomile** and **Tulsi**.
- **Mechanical drying:** Techniques such as **hot air drying** or **freeze-drying** are used for large-scale operations. **Freeze-drying** helps preserve the structure and potency of the plant by freezing the material and then removing moisture through sublimation.
- **Shaping or Grinding:** For some plants, the material needs to be ground into powder (e.g., **Turmeric** and **Ginger**) or shaped into small chunks or granules (e.g., **Aloe Vera**) for easier processing and consumption. This is commonly done through grinding or cutting.

3. SECONDARY PROCESSING: EXTRACTION OF ACTIVE COMPOUNDS

Once the raw material is dried and shaped, the next step is **secondary processing**, which involves the extraction of **active compounds** from the plant. The method of extraction depends on the type of crop and the desired end product.

A. STEAM DISTILLATION (FOR ESSENTIAL OILS)

For **aromatic crops**, the extraction of essential oils is one of the most important forms of secondary processing. **Steam distillation** is the most widely used method for extracting volatile oils from aromatic plants.

- **Process:** The plant material is placed in a distillation chamber, and steam is passed through it. The steam causes the essential oils to vaporize. These vapors are then cooled and condensed back into liquid form, separating the oil from the water. The oil is collected, and any residual plant material is discarded.
- **Applications:** Essential oils extracted through steam distillation are widely used in **aromatherapy, perfumes, cosmetics, and cleaning products**. Popular crops for steam distillation include **Lavender, Rosemary, Peppermint, and Tea Tree**.

B. SOLVENT EXTRACTION (FOR NON-VOLATILE COMPOUNDS)

For some crops, especially those with a low concentration of essential oils, **solvent extraction** is used to extract bioactive compounds. This method is often employed for plants such as **Ginseng, Aloe Vera, and Echinacea**.

- **Process:** A solvent (typically alcohol, hexane, or ethanol) is used to dissolve the desired bioactive compounds from the plant material. Afterward, the solvent is evaporated, leaving behind concentrated extracts. This method is more effective for extracting **fat-soluble compounds** like alkaloids, flavonoids, and terpenoids.
- **Applications:** The resulting extracts can be formulated into **tinctures**, **capsules**, **ointments**, or **liquid extracts** for **medicinal** or **nutraceutical** applications.

C. COLD PRESSING (FOR CITRUS OILS AND OTHER OILS)

Cold pressing is commonly used to extract oils from seeds, nuts, and fruits, especially for **citrus fruits** like **Lemon**, **Orange**, and **Lime**.

- **Process:** In this technique, the raw plant material (often the peel or rind of the fruit) is mechanically pressed to extract the **essential oil**. The process does not involve heat, preserving the freshness and chemical properties of the oil.
- **Applications:** Cold-pressed citrus oils are primarily used in **aromatherapy**, **flavoring**, and **cleaning products**.

4. REFINING AND PURIFICATION

After extraction, the oil or extract typically undergoes **refining** to remove any impurities or solvents that may have been introduced during the extraction process. **Filtration** and **deodorization** are common techniques used to purify essential oils, ensuring that they meet the required safety and quality standards. This step is essential for maintaining the product's **potency**, **safety**, and **consistency**.

5. FORMULATION AND FINAL PROCESSING

The final stage of processing involves **formulating** the extracted ingredients into market-ready products. Depending on the target market, medicinal and aromatic crops can be transformed into various forms:

- **Herbal Teas:** Dried leaves, flowers, or fruits are blended into tea bags or loose-leaf teas for consumption.
- **Capsules and Tablets:** Plant extracts are dried and powdered, then encapsulated into **capsules** or compressed into **tablets** for oral consumption.
- **Topical Products:** Extracts or essential oils can be formulated into creams, lotions, ointments, or soaps for **cosmetic** and **skincare** applications.

- **Liquids and Syrups:** Some plants, like **Aloe Vera** and **Ginseng**, are processed into concentrated syrups or liquid extracts, used in health drinks, tonics, or wellness shots.
- **Aromatic Products:** Essential oils are often used in **diffusers**, **candles**, or **fragrances** for **aromatherapy** and **home products**.

VALUE ADDITION:

The process of value addition for medicinal and aromatic crops encompasses several techniques, ranging from simple methods like drying and grinding to more advanced techniques like extraction, formulation, and packaging.

A. DRYING AND GRINDING

One of the most basic forms of value addition is **drying** the raw plant material and **grinding** it into powder. This is particularly common for **herbs**, **spices**, and **flowers** that have therapeutic uses. Dried herbs or powders can be sold as ready-to-use products for **herbal teas**, **home remedies**, or **cooking**.

For instance:

- **Ginger** and **Turmeric** can be dried and powdered for use in traditional medicines, culinary applications, or dietary supplements.
- **Mint** and **Chamomile** are often dried and sold in tea bags or as loose-leaf tea.

This basic level of value addition also helps improve the shelf life of these products, which would otherwise be highly perishable in their fresh form.

B. ESSENTIAL OIL EXTRACTION

The extraction of **essential oils** is one of the most important and profitable forms of value addition for aromatic crops. Essential oils are highly concentrated compounds obtained from various plant parts like flowers, leaves, stems, or seeds, and are widely used in **aromatherapy**, **cosmetics**, **pharmaceuticals**, and **cleaning products**.

Methods of extracting essential oils include:

- **Steam Distillation:** The most common method for aromatic crops such as **Lavender**, **Peppermint**, **Tea Tree**, and **Eucalyptus**.
- **Cold Pressing:** Typically used for **citrus** fruits such as **Lemon** and **Orange**.
- **Solvent Extraction:** Employed for flowers or leaves that are delicate, such as **Jasmine** or **Rose**.

Essential oils extracted from plants contain a wide range of **bioactive compounds**, including **terpenes**, **phenolic compounds**, and **flavonoids**, which have applications in health, beauty, and wellness industries.

C. HERBAL EXTRACTS

Another highly lucrative form of value addition is the extraction of bioactive compounds from medicinal plants. These extracts are highly concentrated and contain the active ingredients responsible for the therapeutic effects of the plant.

- **Tinctures:** Alcohol-based extracts of herbs like **Ashwagandha**, **Echinacea**, and **Ginseng** are often sold as medicinal tinctures, offering a convenient way for consumers to access the benefits of these plants.
- **Water or Glycerin-Based Extracts:** These extracts are used in teas, syrups, and other herbal supplements. **Aloe Vera**, **Holy Basil (Tulsi)**, and **Chamomile** are popular choices for such extracts.

Extracts can be formulated into **liquid forms**, **capsules**, or **tablets**, and are widely used in **nutraceuticals**, **dietary supplements**, and **functional foods**.

D. HERBAL TEAS AND BEVERAGES

The transformation of medicinal plants into **herbal teas** or **infused beverages** represents a significant area of value addition. Many plants with medicinal properties, such as **Mint**, **Chamomile**, **Lemon Balm**, and **Lemongrass**, are dried and sold as tea blends.

- **Pre-blended Tea Bags:** The convenience of **pre-packaged tea bags** makes herbal teas an accessible and popular product in both local and international markets.
- **Functional Beverages:** Medicinal plants like **Aloe Vera**, **Ginger**, and **Turmeric** are being processed into **health drinks** or **wellness shots** that cater to the growing demand for functional beverages. These drinks not only serve as refreshment but are marketed for their **anti-inflammatory**, **digestive**, and **immune-boosting** properties.

E. COSMETICS AND SKINCARE PRODUCTS

Medicinal and aromatic plants have a rich history in **cosmetics** and **skincare**. The bioactive compounds found in plants are widely used for their **antioxidant**, **anti-inflammatory**, **antibacterial**, and **moisturizing** properties.

Value-added products in this category include:

- **Essential oils:** As key ingredients in **aromatherapy** oils, **face serums**, **shampoos**, **soaps**, and **lotions**.
- **Extracts and Infusions:** Used in **creams**, **facial masks**, **lip balms**, and **body scrubs**.
- **Herbal Shampoos and Conditioners:** Products made with plant extracts like **Aloe Vera**, **Henna**, **Neem**, and **Hibiscus** are gaining popularity in the beauty industry due to their natural composition.

F. FUNCTIONAL FOODS AND NUTRACEUTICALS

Another growing area of value addition is the conversion of medicinal crops into **functional foods** and **nutraceuticals**. These products are enriched with beneficial bioactive compounds and are designed to support **health** and **well-being**.

- **Herbal Supplements and Capsules:** Popular herbs like **Ginseng**, **Turmeric**, **Ashwagandha**, and **Garlic** are encapsulated in pill or capsule form and sold as supplements to support immune health, reduce inflammation, or promote mental clarity.
- **Fortified Foods:** Certain crops, such as **Moringa**, **Spirulina**, and **Baobab**, are processed into **powders** that can be added to smoothies, snacks, or baked goods as nutrient-dense ingredients.

G. AGRI-TOURISM AND WELLNESS PRODUCTS

The concept of **agri - tourism** is also an emerging opportunity for value addition. Medicinal and aromatic crops can be showcased through **farm tours**, **herbal workshops**, and **wellness retreats**, where visitors can learn about the plants, their uses, and how they are processed.

- **Farm-to-table experiences** can be created, where visitors partake in the harvesting, distillation, or preparation of herbal products.
- **Wellness resorts** can offer treatments like **aromatherapy**, **herbal baths**, and **massages** using MACs.

3. ECONOMIC AND MARKET OPPORTUNITIES

The global market for value-added medicinal and aromatic products is growing rapidly, driven by consumer preferences for natural, organic, and holistic wellness products. By adding value to medicinal and aromatic crops, farmers and entrepreneurs can tap into diverse markets:

- **Health-conscious consumers** are increasingly looking for natural supplements, teas, and wellness products that promote overall well-being.

- **Cosmetic and skincare industries** continue to adopt **plant-based formulations**, driven by consumer demand for chemical-free products.



Conclusion

In conclusion, the processing and value addition of medicinal and aromatic crops represent a multi-faceted opportunity that extends far beyond the mere cultivation of these plants. By converting raw crops into high-value products, the agricultural sector can tap into lucrative global markets while contributing to the economic well-being of rural farmers and entrepreneurs. This transformation is essential not just for the profitability of the agricultural sector but also for the broader **health and wellness** industries, which are seeing a surge in demand for natural, plant-based alternatives to synthetic chemicals.

GEOGRAPHICAL DISTRIBUTION AND SPECIES CHARACTERIZATION OF *DODONAEA* GENUS - AN IMPORTANT MEDICINAL PLANT

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Introduction

Dodonaea. viscosa is named after a Flemish botanist, Rembert Dodoens. *D. viscosa* is a small tree or medium-sized shrub that grows upto 9 meters tall. It is commonly called as hope bush and other names include Jamaica Switch Sorrel, hope seed bush, shrubby. In tamil, it is called as virali and in telugu it is named as puli-vailu, respectively. It is having innumerable medicinal benefits and has been utilized by local people all over the world.

Synonyms of *D. viscosa*

The sapindacea family includes more than a 1000 species of plants, most of all they are flowering and woody plants and used as a folk medicine to treat many diseases including cardiac diseases and There are about 20 synonyms are available globally. The most common subspecies are follows:

1. *D. viscosa* subsp. *Angustifolia*
2. *D. viscosa* subsp. *Angustissima*
3. *D. viscosa* subsp. *burmanniana*
4. *D. viscosa* subsp. *cuneata*
5. *D. viscosa* subsp. *mucronata*
6. *D. viscosa* subsp. *Spatulate*

Common names of *D. viscosa*

Africa-Gansies, Kankerbos;

Arabic-Dodonia, Daidon, Dodanaia, Shath;

Australian- broad leaf hopbush, candlewood, giant hopbush, narrow leaf hopbush,

Brazil: faxina-vermelha, vassourão-vermelho,

English- broadleaf hopbush, Florida hopbush, giant hopbush,

Pakistan-Sanatha

India- Hopebush

Important species of *Dodonaea*

D. viscosa, *D. angustifolia*, *D. Microzyga*, *D. boroniifolia*, *D. filiformis*, *D. bursariifolia*, *D. concinna*, *D. coriavea*, *D. filifolia*, *D. hackettiana*, *D. Hexandra*, *D. triquetra*.

2. Geo graphical distribution of *D. viscosa*

The center of origin of *D. viscosa* is believed to be Australia, but it occurs throughout the tropics and subtropics. The plant is distributed in Africa (Kenya; Tanzania; Uganda, Ethiopia, Somalia, Sudan, Angola, Malawi, Mozambique, Zambia, Zimbabwe, Botswana, South Africa, Ghana, Nigeria, Senegal, Togo, Cameroon, Zaire, Madagascar, Mauritius, Reunion, Seychelles); Asia (Saudi Arabia, China, Japan, Afghanistan, Iran, Iraq, India, Pakistan, Sri Lanka, Myanmar, Thailand, Vietnam, Indonesia, Malaysia, Philippines); Australasia (Australasia, New Zealand); Northern America (Mexico, United States); Southern America (Brazil, Bahamas, Bermuda, Cuba, Dominican Republic, Grenada, Guadeloupe, Haiti, Jamaica, Martinique, Puerto Rico, Trinidad and Tobago, Suriname, Venezuela, Argentina, Chile, Uruguay, Bolivia, Colombia, Ecuador, Peru) (Al-Snafi, 2017)



Fig.1. Map displaying the natural geographical distribution of the plant Hopebush

3. Species characterization of *Dodonaea*

D. angustifolia or Sand olive, is a tiny tree or shrub that can reach a height of 8 meters. It has narrow, lance-shaped leaves that are shiny and sticky. It produces small, greenish flowers and winged fruits that are green, red, or brown. It is native to Africa, Arabia, Australia, and New Zealand. It can grow in various habitats, from arid to moist, and can tolerate rocky and poor soils.



D. angustifolia

D. microzyga is also known as brilliant hopbush, because of its bright red winged fruits that look like hops. It is a shrub or small tree that can grow up to 6 feet tall and has narrow, dark green leaves with tiny leaflets. It is native to Australia, where it grows in various habitats, from arid to moist, and can tolerate rocky and poor soils.



D. microzyga

D. ceratocarpa is also known as horny hopbush, because of its winged fruits that resemble horns. It is a shrub or small tree that can grow up to 2.5 meters tall and has oval-shaped leaves that are shiny and sticky. It produces small, cream-green flowers that are mainly seen from May to October.



D. ceratocarpa

D. boroniifolia has both interesting foliage and colourful capsules. The 4-winged capsules that appear after flowering are an eye-catching purplish-red. The dark green foliage contrasts with the capsules. The plant has colorful capsules that appear after flowering. The capsules are an eye-catching purplish-red and contrast with the dark green foliage



D. boroniifolia

D. filiformis is a moderately uncommon but widespread species in dry forests. It is a medium sized, erect shrub with very narrow sticky leaves typically a couple of cm long. The three-winged fruit are unique to this species and it's more common relative to *D. viscosa*.



D. filiformis

D. bursariifolia is also called as small hop-bush. It has simple, sessile, obovate, leaves sometimes oblong, rarely broad-obovate, obtuse or rounded at the apex, not viscous and its flowers are usually 2 or 3 together, rarely in a few-flowered terminal cyme, pedicels 1.5-2.6 mm long; sepals 5, rarely 4, linear to linear-lanceolate, caducous; stamens usually 8, rarely as few as 5, The capsules are usually 3-angled, rarely 4-angledobovate in lateral view, 0.5-1 mm broad, usually present as narrow wings extending the length of the capsule or rarely only above the middle of the capsule.



D. bursariifolia

D. concinna is commonly known as “sand olive” and is native to Australia. The plant is a shrub or small tree that grows up to 5 meters tall. The leaves are simple, alternate, and oblong in shape. The flowers are small and greenish-yellow in color, and the fruit is a capsule with two or three wings



D. concinna

D. hackettiana is commonly known as Hackett’s Hop-bush and is endemic to the Western Australia.. The plant is an erect shrub or small tree that grows up to 5 meters tall. The flowers are yellow-green in color and bloom mainly from July to October. The fruit is a showy three-winged capsule that is yellow to red or orange-brown in color.



D. hackettiana

D. hexandra is commonly called as horned hop-bush found in Southern Australia. The dioecious spreading shrub grow up to 0.6 meter tall;



D. hexandra

simple leaves, sessile, linear, channeled below, convex above, acute, 0.6-1.5, rarely to 3.5 x 0.1-0.2 cm, viscous, with raised glands, glabrous, margin entire and strongly revolute and its flowers solitary or rarely 2 together, axillary or terminal; pedicels 1-1.5 mm long; sepals 3, ovate, 1.5-3.6 mm long, persistent; stamens 6; ovary glabrous and its flowering time is around May – July. The fruit capsules are 3-angled, angular-obovate glabrous with appendages.

D. triquetra is a species of shrub that is native to eastern Australia. It is also known as large leaf hop bush. With elliptic leaves that are 5 to 12 cm long and 1 to 5 cm wide, the plant can reach a height of 3 meters as an upright shrub. The seeds develop on a winged capsule that is 9 to 16 mm long, while the blooms are borne on panicles. This plant is used as a decorative plant for gardens and as a potted plant, and early settlers utilized its capsules as a hop replacement.



D. triquetra

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UNVEILING THE TRANSCRIPTOME: TOOLS AND TECHNIQUES FOR GENE EXPRESSION ANALYSIS

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Introduction

The genome holds the master blueprint of life. Every trait, response, and development in an organism stems from the biological information encoded in its DNA. Genome is a store of biological information but on its own it is unable to release that information to the cell. For these instructions to be carried out, DNA must be transcribed into corresponding molecules of ribonucleic acid, referred to as transcripts. The initial product of the genome expression is the transcriptome. These RNA molecules, referred to as *transcripts*, form what scientists call the transcriptome—the dynamic, functional output of the genome. Understanding the transcriptome provides insight into which genes are active, how they are regulated, and how cells adapt to developmental cues or environmental stimuli. This field of study is known as transcriptomics, and it has revolutionized biology, medicine, and agriculture in the post-genomic era. The following section details the key techniques that have shaped and continue to advance transcriptomic research.

Transcriptome

The transcriptome refers to the complete set of RNA molecules—both coding and non-coding—that are transcribed from the genome under specific developmental stages or physiological conditions. This includes messenger RNA (mRNA), which codes for proteins, as well as various non-coding RNAs such as transfer RNA (tRNA), ribosomal RNA (rRNA), and other regulatory RNAs.

The term "transcriptome" was first introduced by scientist Charles Auffray to describe the entire collection of RNA transcripts produced in a cell or organism.

Transcriptomics

Transcriptomics is the branch of science that focuses on the study of the **transcriptome**—the complete set of RNA transcripts produced by the genome under specific conditions. It plays a crucial role in the **post-genomic era**, providing deep insights into gene expression, regulation, and function. Transcriptomic analysis enables researchers to examine **global gene expression patterns** across different tissues, developmental stages, or in response to various internal and external stimuli. This helps in understanding how an organism's genome dynamically responds to physiological and environmental cues.

The importance of transcriptomics lies in its ability to profile **mRNA transcripts**, which represent the actively expressed genes in a cell at a given time. Through transcriptomic studies, scientists gain valuable information about **gene structure, expression levels, and regulatory mechanisms**. This field has been widely applied across a range of organisms, contributing significantly to advances in functional genomics, systems biology, and precision breeding.

Methodologies for Transcriptomic Analysis

The dynamic nature and complexity of the transcriptome necessitate a variety of specialized methodologies for its investigation. These techniques offer different levels of resolution, throughput, and focus, each contributing uniquely to our understanding of gene expression.

SAGE

Serial Analysis of Gene Expression (SAGE) was the first sequencing-based technique to concurrently estimate the abundance of thousands of transcripts. This method is predicated on the idea that, given the position of the sequence within the transcript is known, a short DNA sequence (tag) of 9–11bp, taken from a specific point inside one transcript, carries enough information to specifically identify that transcript. SAGE calculates the abundance of the transcripts by counting the tags. The tags are tallied to determine the relative abundance of the respective transcripts, and tag sequences are compared to reference sequences in other databases to identify the transcripts. These cDNA tags are then concatenated head to tail into long strands and sequenced using low throughput but long read length methods such as Sanger sequencing. These clones are sequenced using normal Sanger sequencing. SAGE has various benefits over

other approaches like EST sequencing and microarrays. SAGE provides quantitative transcriptome analysis and is useful in discovering novel genes. However, there are several limitations of this technique including the difficulties in identifying unknown genes due to the short length of tags, specificity issues due to overlapping sequences, and potential incompatibilities with some restriction enzymes.

Microarray

Microarrays are a high-throughput technique used to concurrently evaluate the expression levels of thousands of genes. Thousands of DNA probes must be immobilized on a solid surface before they can be hybridized with labelled cDNA or RNA from a sample. Transcript abundance is determined by hybridization of fluorescently labelled transcripts to these probes. The fluorescence intensity at each probe location on the array indicates the transcript abundance for that probe sequence. Many DNA samples are used to construct an array. The amount of mRNA bound to each site on the array indicates the expression level of the various genes. Microarrays are significantly cheaper than RNA sequencing. The data generated by microarrays are smaller and easier to manage. However, this method may not effectively detect genes with very low expression levels and new transcripts.

RNA-Seq

RNA sequencing (RNA-seq) is a sequencing-based technique that enables the measurement of gene expression levels and the discovery of new transcripts. It refers to the combination of a high through-put sequencing methodology with computational methods to capture and quantify transcripts present in an RNA extract. RNA-seq entails cDNA synthesis, cDNA fragment sequencing and read mapping to a reference genome or de novo assembly. This method gives a better approximation of the absolute expression levels and is more dynamic. RNA-Seq combines high-throughput sequencing with computational methods to quantify RNA transcripts. This novel technology is based on next-generation sequencing (NGS) platforms which are highly automated. The RNA-Seq process begins with the extraction of mRNA and converting it into stable cDNA. The cDNA fragments are sequenced using high-throughput methods. The raw sequencing data are then processed to generate a counts table. This data is used to annotate gene expression levels. Various online tools are available for data processing.

RT-PCR

Reverse transcription polymerase chain reaction (RT-PCR) is a method for measuring the levels

of gene expression in certain genes. RNA is reverse transcribed into cDNA, and the cDNA is then amplified using PCR using particular primers.

Ribosome profiling

This sequencing-based technique allows for the evaluation of the ribosome occupancy and translational efficacy of mRNA transcripts. It identifies actively translated transcripts and analyzes translation start and elongation, which entails extracting ribosome-protected mRNA segments and sequencing them.

Nanostring

It is a hybridization-based technique that enables the simultaneous assessment of up to 800 genes' levels of gene expression. It entails utilizing target-specific probes to capture certain RNA transcripts, followed by a computerized counting technique to quantify the transcripts.

Iso-seq

Isoform sequencing is the method that uses sequencing to characterize full-length mRNA transcripts. It identifies alternative splicing events and transcript isoforms, it entails sequencing cDNA segments that have been size-selected to include only full-length transcripts.

Expressed Sequence Tag (EST) Sequencing

ESTs are short nucleotide sequences produced from a single RNA transcript, usually within the range of 100-700bp. The process of EST sequencing begins by converting RNA into complementary DNA (cDNA) using reverse transcription, followed by sequencing the cDNA. ESTs are often generated by single pass sequencing of cDNA clones from one or both ends. In recent years, high-throughput and large data output have made RNA-Seq the dominant method and replaced conventional EST sequencing. Although modern high-throughput methods have largely replaced them, EST libraries played an important role in early microarray designs and still plays an important role in gene identification, transcript mapping and description of the transcriptional activity of a tissue/ cell type.

scRNA-seq

Single-cell RNA sequencing (scRNA-seq) is a sequencing-based technology that enables the analysis of the gene expression patterns of individual cells. It entails isolating and sequencing the transcriptome of a single cell, enabling the recognition of cell subtypes and the variance in gene expression from cell to cell.



Transcriptomics is a fundamental tool in modern biology. It lets us see beyond the static genetic blueprint to understand which genes are active at any given moment in different situations, tissues, or even individual cells. The rapid development of these methods—from early techniques to advanced sequencing and single-cell analysis—shows how far molecular biology has come. These powerful tools help scientists gain dynamic insights into how genes function, how cells behave, how organisms develop, and the mechanisms behind diseases. As these technologies improve and become more widely available, they'll continue to drive major discoveries in biological research, medicine, and biotechnology.



ADOPTION LEVELS OF PRADHAN MANTRI FASAL BIMA YOJANA (PMFBY) AMONG FARMERS IN DINDIGUL DISTRICT, TAMIL NADU

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Abstract

Agriculture plays a crucial role in India's economy, but farmers face multiple risks such as unpredictable weather, natural calamities, and pest infestations, which impact their income and livelihood. To address these challenges, the Government of India launched the Pradhan Mantri Fasal Bima Yojana (PMFBY) in 2016, a comprehensive crop insurance scheme aimed at providing financial security to farmers. This study assesses the knowledge and adoption levels of PMFBY among farmers in Dindigul district, Tamil Nadu. An ex-post facto research design was used, and data were collected from 60 farmers selected through proportionate random sampling. The findings reveal that 76.70 per cent of respondents had a medium level of adoption, while 15.00 per cent had a high level of adoption. Correlation analysis showed that education qualification, types of farmers, and farming experience had a significant positive relationship with PMFBY adoption. The study highlights the need for increased awareness programs and simplified insurance processes to enhance farmer participation.

Keywords: Pradhan Mantri Fasal Bima Yojana, Crop Insurance, Farmers' Adoption, Adoption, Tamil Nadu.

Introduction

Agriculture is the backbone of India's economy, providing employment to nearly 58.00 per cent of the population. Despite its significance, the sector remains vulnerable to risks such as erratic weather conditions, natural disasters, pest infestations, and price fluctuations, which contribute to financial distress among farmers. Crop insurance is a vital risk management tool that safeguards farmers against potential yield losses due to these adversities.

To address these challenges, the Government of India launched the Pradhan Mantri Fasal Bima Yojana (PMFBY) on January 13, 2016, as a comprehensive crop insurance scheme. PMFBY replaced earlier schemes such as the National Agricultural Insurance Scheme (NAIS) and the Modified National Agricultural Insurance Scheme (MNAIS). The scheme aims to provide affordable, technology-driven, and transparent crop insurance, ensuring financial stability for farmers. Advanced technologies like remote sensing, satellite imagery, drones, and smartphone-based crop monitoring are leveraged to improve transparency and expedite claim settlements.

The primary objectives of PMFBY include:

- ✓ Providing financial protection to farmers against crop losses.
- ✓ Ensuring prompt claim settlements through advanced technology.
- ✓ Encouraging sustainable agricultural practices.
- ✓ Increasing farmer participation in crop insurance schemes.

This study assesses the knowledge and adoption levels of PMFBY among farmers in Dindigul district, Tamil Nadu, and explores the factors influencing their participation.

Objectives

- Socio-economic characteristics of the respondents PMFBY.
- To assess the relationship between adoption of PMFBY beneficiaries.

Methodology

Research Design

The study adopts an ex-post facto research design, which is suitable when the variables have already occurred, and the researcher analyzes their effects without direct manipulation.

Selection of Study Area

Selection of District

Dindigul district of Tamil Nadu was chosen due to its agricultural significance and active government scheme implementation. The researcher's familiarity with the local language and farming practices facilitated effective data collection.

Selection of the Block and Village

Among the 14 blocks in Dindigul district, Athoor and Reddiarchatram blocks were selected. The villages chosen for the study were Athoor, Aiyampalaiyam, Dharumathupatti, and Palakannatham.

Sampling Method and Sample Size

A list of PMFBY beneficiaries was obtained from Village Administrative Officers. Proportionate random sampling was used, and 60 respondents were selected.

Statistical Tools Used

Descriptive Statistics: Frequency, percentage, mean, and standard deviation were used to analyze respondents' socio-economic characteristics.

Correlation Analysis: The relationship between independent variables (age, education, occupation, etc.) and knowledge of PMFBY was examined.

Results and Discussion

Extent of Adoption of PMFBY

The adoption level of PMFBY was categorized into low, medium, and high based on farmers' enrolment, claim submission, and perceived benefits.

Table 1: Distribution of respondents according to their extent of adoption – PMFBY
(n = 60)

S.NO	Category	Respondents	
		f	%
1	Low	05	08.30
2	Medium	46	76.70
3	High	09	15.00
	Total	60	100.00

It was observed from the data presented in Table 1, that majority of the respondents (76.70 per cent) had medium level of adoption about Pradhan Mantri Fasal Bima, (15.00 percent) of respondents had high level of adoption about Pradhan Mantri Fasal Bima

Yojana, whereas (08.30 per cent) of respondents had low level of adoption about Pradhan Mantri Fasal Bima Yojana.

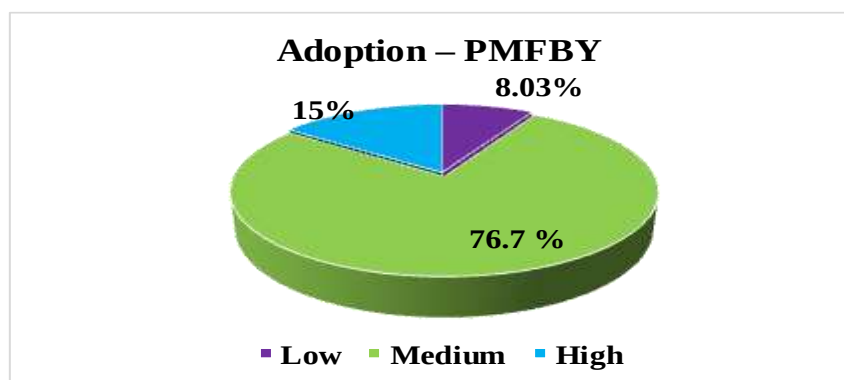


Figure: 1. Adoption – PMFBY

Relationship between Independent Variables and PMFBY Adoption

Correlation analysis was conducted to determine the relationship between adoption levels and selected socio-economic factors.

Table 2: Correlation coefficient of independent variables with PMFBY adoption

S. No	Independent variables	r' value
1	Age	-0.197
2	Education Qualification	0.534**
3	Occupation	0.011 ^{NS}
4	Category	-0.231 ^{NS}
5	Religion	0.076 ^{NS}
6	Total. no. of family members	0.152 ^{NS}
7	Types of farmers	0.326*
8	Farming Experience	0.288*

*Significant at 0.05 per cent level.

**Significant at 0.01 per cent level.

NS- Non-significant

Table 2. Indicate that Education Qualification, Types of farmers and Farming Experiences showed positive and highly significant relationship with adoption of respondents about Pradhan Mantri Fasal Bima Yojana.



Whereas, occupation, Religion and Total number of family members showed positive and non-significant relationship while, Age and Category showed negative and non-significant relationship with knowledge of respondents about Pradhan Mantri Fasal Bima Yojana.

Conclusion

This study examined the adoption and knowledge levels of PMFBY among farmers in Dindigul district. The results revealed that most farmers had a medium level of adoption, with education and farming experience significantly influencing participation. The findings suggest that enhancing awareness programs, improving accessibility, and simplifying insurance processes could boost PMFBY adoption rates. Government and extension agencies should focus on addressing barriers such as delayed claim settlements and complex documentation procedures. Future research could explore the impact of digital platforms in increasing PMFBY enrolments among farmers.

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UNLOCKING NATURE'S TREASURE: SILICA EXTRACTION FROM DIVERSE SOURCES AND ITS AGRICULTURAL APPLICATIONS

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Abstract

Silica (SiO_2), a naturally abundant compound in the Earth's crust, is increasingly recognized for its multifaceted role in sustainable agriculture. Traditionally known as a component of sand and quartz, silica is also found in crop residues, industrial waste, and certain mineral resources. Among various sources, rice husk ash and coal-derived materials have emerged as promising alternatives for extracting bioavailable silica due to their cost-effectiveness and high silica content. This article explores diverse sources of silica, with a focus on the sol-gel extraction method—a reliable technique for producing high-purity amorphous silica suitable for agricultural use. The role of silica in enhancing plant structure, tolerance to stress, resistance to pests and diseases, and improvement of soil health is discussed in detail. Additionally, the potential of silica as photocatalysis and its implications for environmental applications are highlighted. The article emphasizes the need for integrating silica-based amendments into modern farming practices as a step toward sustainable land use and resource recycling.

Introduction

Silica, or silicon dioxide (SiO_2), is a naturally occurring compound found abundantly in the Earth's crust. While it is best known as a primary component of sand and quartz, it is also present in plants, crop residues, and industrial by-products. Rice husk silica (RHS) has become a viable substitute for conventional silica sources due to its cost-effectiveness, adaptability, and environmentally benign qualities (Taiye et al. 2024). Because of its great availability and

numerous benefits in various disciplines, silica has gained popularity as a material. In recent years, silica has gained attention in agriculture, especially for its role in improving plant resilience and soil health (Luthfiah et al. 2021). This substance can be harvested from nature and created synthetically, which has benefits for the use of green production.

Sources of Silica: A Hidden Wealth

Silica is available from a wide range of natural and industrial sources:

1. **Plant-Based Residues:** Rice husk, wheat straw, sugarcane bagasse, and other biomass residues are rich in amorphous silica. When these materials are burned or treated, they leave behind silica-rich ash.
2. **Industrial Waste:** Fly ash from thermal power plants and coal combustion, slag from steel industries, and by-products from cement manufacturing often contain significant amounts of silica, sometimes in a reactive form that can be made available to plants.
3. **Natural Minerals:** Quartz, diatomaceous earth, and certain types of clay are geological sources of silica. However, these are mostly crystalline and less soluble, requiring treatment for agricultural use.
4. **Coal-Derived Materials:** By-products like sintered coalchar, especially from bituminous coal processing, have shown potential due to their mineral composition, including soluble forms of silica. Burning a variety of mineral coals produces fly ash, a complex derivative with a 45–60% SiO_2 content. This substance has spherical vitreous particles that range in size from 8 to 20 μm and is thought to be less dense than cement. Additionally, mesoporous silica ash synthesis has garnered interest due to the properties of the final product (Wang et al., 2020).

Extraction Techniques: Turning Waste into Wealth

Depending on the material, different silica extraction methods can be applied. One of the most advanced and effective among these is the **Sol-Gel method**:

Sol-Gel Method

One of the most efficient ways to recover silica from plant-based or industrial materials is through the sol-gel method. This technique involves a two-step chemical transformation. First, the silica-rich material—such as rice husk ash, fly ash, or sintered coalchar—is mixed with a sodium hydroxide solution. This reaction breaks down the solid matrix and converts the silica into a liquid form known as sodium silicate. In the next step, a weak acid like hydrochloric or

citric acid is gradually added to the sodium silicate solution. As the pH drops, a soft gel begins to form—this is the sol-gel transition. The gel is then allowed to age, which stabilizes its structure. After that, it is washed thoroughly with water to remove any remaining salts or by-products and finally dried into a fine, white powder. This resulting material is highly porous, amorphous silica that plants can readily absorb. What makes this method particularly useful is that it produces high-purity silica using low-cost chemicals and can be easily adapted for both laboratory and small-scale farm use.

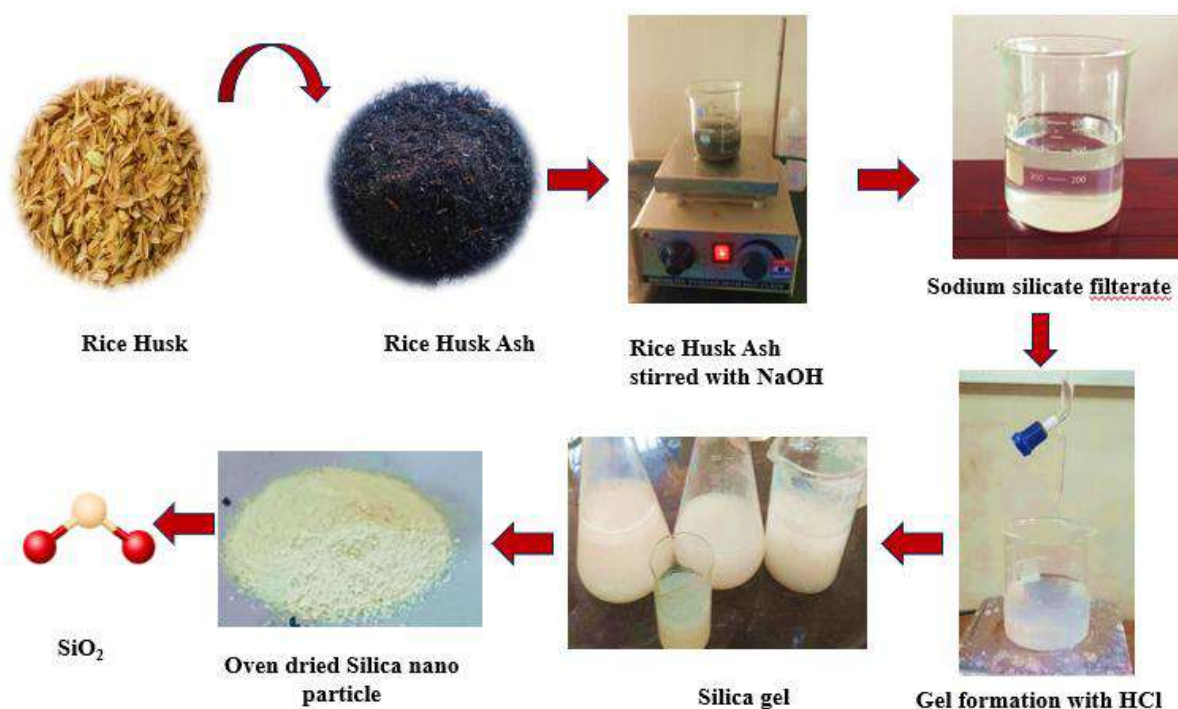


Figure 1. Silica extraction from rice husk by Sol gel method.

Silica in Agriculture

While not classified as an essential element, silicon is a **beneficial nutrient** for many crops, especially cereals like rice, wheat, and maize.

Reinforces Plant Structure:

Once absorbed, silica is deposited in the cell walls of plant tissues, forming a protective layer that strengthens stems and leaves. This structural support helps crops like rice, wheat, and sugarcane stand upright, significantly reducing the risk of lodging during high winds or heavy rainfall.

Enhances Stress Tolerance:

Silica acts as a silent shield against environmental stress. It improves water retention within plant cells, enabling better performance during drought. Additionally, it reduces the uptake of harmful ions such as sodium and heavy metals, making plants more tolerant to saline or contaminated soils.

Increases Resistance to Pests and Diseases:

Silicon fortifies the outer layer of plants, creating a barrier that deters pests and reduces pathogen entry. Beyond physical defense, it also stimulates internal resistance mechanisms, helping the plant activate natural immune responses against fungal and bacterial infections.

Improves Soil Quality and Fertility:

Silica-based amendments contribute to better soil structure by promoting the formation of aggregates, which enhances aeration and root penetration. In sodic soils, silica helps displace sodium ions, reducing soil alkalinity. Moreover, it facilitates the release and availability of essential nutrients like phosphorus and micronutrients, supporting healthier and more balanced plant growth.

Silica as Antibacterial Photocatalysis:

The function of silica as a supporting material for a photocatalyst in the photocatalytic process is one of its many uses. Light components and photocatalysts are needed for this process, which combines chemical reactions to speed up chemical transformations. Due to its bonding and antibonding bands that are separated by bandgap energy, this chemical is typically a semiconductor.

The Road Ahead: From Lab to Land

Transforming silica-rich residues into value-added soil amendments is a sustainable way to manage agricultural and industrial waste. Developing bioactivated silica fertilizers using organic acids or microbes, especially from coalchar or rice husk ash, can offer an eco-friendly alternative to synthetic inputs. Farmers, researchers, and industries must collaborate to scale up these technologies, creating low-cost, efficient silica supplements that promote sustainable farming and soil restoration.

Conclusion

Silica, once overlooked in mainstream agriculture, is now gaining importance as a sustainable input for improving crop productivity and soil quality. Through innovative extraction

methods like the sol-gel process, silica can be effectively recovered from agricultural and industrial residues, transforming waste into a valuable resource. Its contribution to plant strength, stress tolerance, and soil health makes it a viable supplement in both conventional and stress-prone farming systems. Furthermore, the functional properties of silica extend beyond agriculture, offering opportunities in photocatalytic and environmental applications. Moving forward, the development of low-cost, bioavailable silica products especially those enriched with microbial or organic activators can support eco-friendly agriculture. Collaborative efforts among researchers, industries, and farmers will be key to unlocking the full potential of silica for sustainable development.

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CONNECTING WITH NATURE IN THE DIGITAL AGE: IMPACT AND IMPLICATIONS

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Abstract

In the digital era, social media has become a powerful force shaping how individuals perceive and engage with the world around them—including the natural environment. This paper investigates the evolving relationship between humans and nature in the context of increasing social media use. Platforms like Instagram, YouTube, and Facebook offer constant exposure to curated images and videos of nature, which can foster environmental awareness and inspire outdoor activity. However, these platforms can also create a superficial bond with nature, where the experience is often driven by aesthetics, trends, and online validation rather than genuine appreciation. Through qualitative analysis of user-generated content and surveys exploring digital habits, this research reveals a paradox: social media connects users to nature virtually while simultaneously distancing them from real, immersive experiences. The findings underscore the importance of promoting mindful digital practices that encourage authentic engagement with the natural world. As we redefine social connection in the digital age, striking a balance between technology and nature is essential for long-term ecological awareness and emotional well-being.

Keywords

Social media, digital age, nature connection, environmental awareness, virtual experience, ecological engagement, online validation, Instagram culture, digital mindfulness

Introduction

In an era defined by rapid technological advancement and constant connectivity, the way



we relate to the natural world is undergoing a profound transformation. As screens dominate daily life and digital platforms mediate many of our experiences, a growing concern has emerged about the diminishing time people spend in direct contact with nature. At the same time, technology also offers innovative ways to explore, understand, and protect the environment, from virtual nature walks to real-time wildlife monitoring.

This paradox—of being simultaneously more informed about and more detached from nature—raises important questions about how digital tools are reshaping our relationship with the natural world. Are we enhancing our connection to nature through technology, or are we replacing it with simulations? What are the psychological, environmental, and societal consequences of this shift?

Therefore, it is imperative to explore the impact and implications of connecting with nature in the digital age, along with examining both the benefits and challenges of this evolving relationship. By understanding the dual role that technology plays, we can seek ways to harmonize digital innovation with a renewed commitment to experiencing and protecting the natural world.

The Historical Context of Human-Nature Relationships

The relationship between humans and nature has evolved dramatically over the course of history, shaped by cultural values, technological developments, and societal needs. Understanding this historical context provides valuable insight into how the digital age fits into a broader narrative of human interaction with the natural world.

Pre-Industrial Societies: Integration with Nature

In early human history, nature was not a separate entity but a central part of daily life. Indigenous and agrarian societies lived in close connection with the land, relying on natural rhythms for agriculture, hunting, and survival. Spiritual and cultural practices are often centered around natural elements, reflecting a deep reverence for the environment. These communities tended to view themselves as part of a larger ecosystem, with sustainable practices born from necessity and respect. The environment was both a provider and a teacher, shaping the identity and values of those who depended on it.

The Industrial Revolution: Separation and Exploitation

The onset of the Industrial Revolution in the 18th and 19th centuries marked a turning point. As machines and fossil fuels began to power human progress, nature increasingly came to

be seen as a resource to be harnessed and controlled. Urbanization and mechanization reduced daily contact with the natural world, and landscapes were altered on a massive scale to accommodate factories, railways, and expanding cities. This period also saw the emergence of a dualistic view: humans versus nature. While some thinkers, like the Romantics and early environmentalists, lamented the loss of connection, the dominant narrative favored progress over preservation.

20th Century: Conservation and Environmental Awareness

The 20th century witnessed growing awareness of environmental degradation, prompting the rise of conservation movements and environmental policy. Influential works such as Rachel Carson's *Silent Spring* and the establishment of Earth Day in 1970 catalyzed a global recognition of the need to protect natural ecosystems. At the same time, modern lifestyles became increasingly urban and technologically dependent, further distancing people from nature. This paradox—heightened awareness paired with reduced interaction—laid the groundwork for the dilemmas of the digital age.

Digital Age: A New Frontier

Today, digital technology is redefining the human-nature relationship once again. While it offers tools to visualize, document, and understand the environment in unique ways, it also risks replacing direct experiences with virtual substitutes. This historical trajectory—moving from immersion to separation and now to simulation—underscores the importance of critically evaluating how we engage with nature in a screen-saturated world.

Social Media as a Mediator of Nature Experiences

The Visual Aesthetic of Nature

Social media platforms prioritize visual content, leading to the rise of "nature influencers" and viral nature photography. National parks, remote trails, and pristine beaches have become backdrops for curated images. This visual framing can increase environmental appreciation but also risks reducing nature to a backdrop for personal branding.

Virtual versus Physical Engagement

Studies show that while virtual exposure to nature can improve mood and inspire ecological concern, it often does not translate to increased outdoor activity. Moreover, constant digital documentation may shift attention away from immersive experience toward content creation.

Benefits of Social Media for Environmental Awareness

Social media can serve as a powerful tool for ecological education and activism. Movements like #FridaysForFuture and #PlasticFreeChallenge have mobilized millions globally, spreading awareness and prompting behavioral change. Digital campaigns can connect like-minded individuals and amplify marginalized environmental voices, democratizing environmental discourse.

The Risks: Commodification and Environmental Degradation

The intersection of social media and environmentalism has introduced both opportunities and challenges. While platforms like Instagram and TikTok have democratized access to natural wonders, they have also contributed to the commodification of nature. As destinations gain popularity through viral posts, they often suffer from over-tourism, leading to ecological damage. Trails become eroded, wildlife is disturbed, and waste management systems are overwhelmed, highlighting the tension between awareness and exploitation. This phenomenon underscores the complexities of promoting environmental consciousness in the digital age.

Eco-Tourism and Overexposure

Places that gain popularity through viral posts often suffer from over-tourism, leading to ecological damage. Trails become eroded, wildlife disturbed, and waste management systems overwhelmed. This highlights the tension between awareness and exploitation.

Performative Environmentalism

“Clicktivism” and “green washing” are concerns in the age of social media. Users may share environmental content for social approval rather than genuine concern, diluting the impact of activism and reducing complex issues to digestible, often misleading content.

Reimagining the Digital-Nature Nexus

To move toward a more constructive relationship, social media use must be intentional. Strategies include

- Promoting responsible tourism through geotagging policies.
- Encouraging offline nature experiences via challenges or community initiatives.
- Supporting content that reflects ecological complexity, not just beauty.

Education and platform policy also play a role in shaping user behaviour. Influencers and environmental organizations can help lead the shift from spectacle to stewardship.

Conclusion

The digital age has brought about a complex and often contradictory transformation in the way we connect with nature. On one hand, technology offers unprecedented opportunities to learn about, explore, and protect the environment—from satellite monitoring of ecosystems to apps that encourage outdoor discovery. On the other hand, it also contributes to growing disconnection, as daily life becomes increasingly mediated by screens and virtual experiences. Understanding the historical context of our relationship with nature reveals that this is not the first time human progress has reshaped how we engage with the natural world. However, the current moment is unique in its global scale and the speed at which digital innovation is advancing.

The challenge we face is not to reject technology but to use it wisely—to design and adopt digital tools that encourage, rather than replace, direct interaction with nature. By striking a balance between innovation and intimacy with the natural world, we can foster a deeper, more sustainable relationship with the environment. Ultimately, reconnecting with nature in meaningful ways—both through technology and beyond it—is essential for personal well-being, ecological stewardship, and the future of our planet.

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PHYTOHORMONES IN SEED BIOLOGY: ROLES, INTERACTIONS, AND MECHANISMS

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Abstract

Plant hormones, or phytohormones, play a vital role in regulating seed development and germination, ensuring proper growth, maturation, and the transition to a viable seedling. Key hormones such as abscisic acid (ABA), gibberellins (GAs), auxins, cytokinins, and ethylene orchestrate complex physiological and molecular processes. ABA promotes seed maturation, dormancy, and desiccation tolerance, while GAs break dormancy and initiate germination by stimulating enzyme production. Auxins aid in embryogenesis and cell differentiation, whereas cytokinins contribute to nutrient mobilization and growth. Ethylene facilitates germination under stress and modulates seedling emergence. Understanding hormonal interactions is crucial for improving seed quality, crop yield, and stress resilience.

Keywords: Phytohormones, Seed Development, Germination, Hormonal Regulation, Absciscic Acid, Gibberellins

Introduction

Natural chemical substances called phytohormones, sometimes referred to as plant hormones, are essential for controlling the growth, development, metabolism, and reactions of plants to external stimuli. Phytohormones, in contrast to animal hormones, are made in a variety of plant tissues rather than by specialized glands. By functioning as chemical messengers, they have a significant impact on physiological processes even at very low concentrations.

Auxins, gibberellins (GA's), cytokinins, abscisic acid (ABA), and ethylene are the five main groups of phytohormones. Furthermore, the hormone-like activity of other signalling molecules in plants has been identified, including strigolactones, salicylic acid, jasmonates, and brassinosteroids. Cell division, elongation, seed development, dormancy, germination, flowering, fruit ripening, and stress responses are just a few of the vital processes that these hormones frequently modulate in a highly coordinated and dynamic way.

Plant survival and adaptability depend heavily on phytohormones. Through the regulation of biosynthesis, transport, perception, and gene expression, their signalling networks are strictly controlled. Crops with increased yield, stress tolerance, and growth regulation have been made possible by new discoveries in plant biology and agriculture brought about by an understanding of phytohormone pathways and their interactions.

Types of hormones

Plant hormones or phytohormones, are vital regulators of seed development and germination. They coordinate complex physiological and biochemical processes that control seed maturation, dormancy, and germination. The key hormones involved are abscisic acid (ABA), gibberellins (GA), auxins, cytokinins, and ethylene. Each plays a specific and sometimes opposing role during these stages.

1. Absciscic Acid (ABA)

A vital phytohormone, abscisic acid (ABA) is involved in many physiological processes, especially the development, maturation, induction of dormancy, and prevention of germination of seeds. It serves as a regulatory switch, guaranteeing that seeds grow correctly and only sprout in ideal environmental conditions.

Function in Seed Development: By encouraging the buildup of storage proteins and desiccation tolerance, ABA plays a critical role in seed maturity.

Function in Germination: By blocking enzymes that degrade food stores, ABA causes and preserves seed dormancy. Premature germination is prevented by high ABA levels, particularly in stressful situations.

2. Gibberellins (GA)

A class of plant hormones known as gibberellins (GAs) is essential for blooming, stem elongation, leaf expansion, and seed germination. By promoting the synthesis of hydrolytic enzymes such as α -amylase, GA's break dormancy during seed germination and release stored

nutrients for the developing embryo. By opposing abscisic acid (ABA), GA's encourage cell elongation and proliferation. They are also necessary for some species' fruit growth and bolting in rosette plants. GA's are essential for total plant growth and production under ideal conditions because they are synthesized in young tissues, control gene expression, and facilitate developmental stage transitions.

Function in Seed Development

GA aids in weakening seed coverings in preparation for germination and affects embryo growth.

Function in Germination

GA stimulates the formation of hydrolytic enzymes, such as α -amylase, in the aleurone layer, which in turn promotes germination. Activating the endosperm's food reserves to promote the growth of the embryo. GA works antagonistically to ABA during germination.

3. Auxins

Auxins are vital hormones in plants that control apical dominance, root initiation, cell elongation, and tropic responses to gravity and light. Indole-3-acetic acid is the main auxin found in nature (IAA). By promoting cell division and expansion and relaxing cell membranes, auxins aid in growth. They are generally made at the tips of shoots and are carried downward. In order to guarantee directed plant growth and coordinated tissue development, auxins also affect the development of vascular tissue, fruit formation, and the suppression of lateral bud expansion.

Function in Seed Development

Auxins regulate embryo patterning and growth. They also assist in proper seed coat and fruit formation.

Function in Germination

Although less directly involved, auxins influence cell elongation during seedling emergence.

4. Cytokinins

Plant hormones called cytokinins stimulate cell division, initiate shoots, and postpone the senescence of leaves. They are mostly produced in the roots of the plant and then moved to other sections. Higher cytokinin levels promote the production of shoots, and they cooperate with auxins to control growth. They also affect the mobilization of nutrients, improve the formation of

chloroplasts, and encourage the growth of young leaves. Cytokinins are essential for plant development, morphogenesis, and stress response systems because they alter gene expression.

Function in Seed Development

During the development of embryos and endosperm, cytokinins play a part in cell division and nutrient mobilization.

Function in Germination

They aid in the initial phases of germination by promoting cell division and growth.

5. Ethylene

Ethylene is a gaseous plant hormone aids in fruit ripening, leaf abscission, flower wilting, and reaction to environmental stress. It is essential for the triple response of seedlings, which includes the suppression of horizontal growth, radial swelling, and stem elongation. Nearly all plant tissue produces ethylene, particularly during ripening, senescence, and stressful situations like floods or wounding. Additionally, it modulates defence responses, growth, and development in plants by interacting with other hormones.

Function in Seed Development: Ethylene has the ability to control the maturation and abscission of seeds.

Function in Germination: Ethylene cooperates with GA to help break seed dormancy. Additionally, it weakens the endosperm and seed coat and encourages the formation of radicles.

Hormonal Interactions

- **ABA vs GA:** These two hormones are the primary antagonists during dormancy and germination. A high ABA/GA ratio promotes dormancy, while a low ratio promotes germination.
- **Ethylene and GA synergy:** Both contribute to breaking dormancy and promoting germination under favourable conditions.

Conclusion

Hormonal networks carefully control the growth and germination of seeds. Whether a seed germinates or remain concealed hinges on the timing and balance of hormone communication, particularly between ABA and GA. Gaining an understanding of these hormonal processes is essential for enhancing agricultural productivity, dormancy control, and seed viability.

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SURVIVAL AND DISPERSAL OF MICROORGANISMS IN NATURE: PAST TO PRESENT

Article ID: AG-VO5-I06-70**Akhila Chandran S¹ and Anu Rajan S²**

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Abstract

Microorganisms are fundamental to life on Earth, playing essential roles in ecosystems, agriculture, and human health. Their ability to endure extreme conditions and spread across diverse environments has made them key players in ecological and industrial processes. This article explores the mechanisms microorganisms use to survive—such as dormancy, spore formation, biofilm development, horizontal gene transfer, syntrophy, and metabolic adaptability—and the various ways they disperse through air, soil, water, and biological vectors. Additionally, human activities such as agriculture, urbanization, and industrial expansion have accelerated microbial movement, influencing global microbial dynamics. Recent advances in synthetic biology, AI-driven microbiome research, and nanotechnology are revolutionizing our understanding of microbial survival and dispersal. By harnessing microbial potential, we can develop innovative applications in medicine, agriculture, and environmental sustainability, ensuring their continued contribution to life on Earth.

Keywords: Survival, dispersal, microbes in nature

Introduction

Microorganisms are the unseen architects of life on Earth, playing critical roles in ecosystems, agriculture, and human health. Their ability to survive in harsh conditions and disperse across vast distances is nothing short of remarkable. This article explores the fascinating

strategies microorganisms employ to endure and spread and how modern environmental changes influence these mechanisms.

Modes of Survival: How Microorganisms Endure Harsh Conditions

Dormancy and Metabolic Slowdown

When conditions become unfavorable, many microorganisms enter a dormant state, drastically reducing their metabolic activity to conserve energy. This strategy is evident in bacteria that adopt a "viable but non-culturable" (VBNC) state, in which they remain alive but cannot be cultured in a lab. Fungi and archaea also employ similar tactics to survive nutrient-poor environments. Recent studies have identified specific genetic markers responsible for dormancy regulation, aiding in predicting microbial revival patterns. Synthetic biology advancements are exploring how dormancy genes can be manipulated for biotechnological applications, such as probiotics and biofertilizers. AI-based models are being developed to predict dormancy activation and its implications in microbial ecology.

Spore Formation: Time Capsules

Spore formation is a key survival strategy among microorganisms, allowing them to withstand extreme conditions. The different spore types and their roles in survival are detailed below:

Bacteria:

- **Endospores (*Bacillus*, *Clostridium*):** Highly resistant to heat, chemicals, and radiation, endospores protect bacterial DNA during extreme stress.
- **Exospores (*Streptomyces*):** Help bacteria survive nutrient deprivation by forming externally on the cell.

Fungi:

- **Conidia (*Aspergillus*, *Penicillium*):** Aid in rapid reproduction and dispersal.
- **Sporangiospores (*Rhizopus*, *Mucor*):** Survive in soil and enable fungal propagation.
- **Chlamydospores (*Fusarium*, *Candida*):** Resist harsh conditions and enable long-term survival.
- **Ascospores (*Saccharomyces*):** Provide resistance to stress.
- **Basidiospores (Mushrooms, rusts, smuts):** Highly resistant to UV radiation and desiccation.
- **Zygospores (*Rhizopus*, *Mucor*):** Help fungi survive drought and cold conditions.

Protozoa:

- **Oocysts (*Cryptosporidium*):** Allow survival in water and soil.
- **Microsporidian Spores (*Nosema*):** Offer protection against environmental stressors.

Algae:

- **Akinetes (*Anabaena*, *Nostoc*):** Protect against desiccation and nutrient limitation.
- **Zoospores (*Chlamydomonas*):** Facilitate rapid colonization of new environments.

Studies have revealed that spores can reactivate after thousands of years, as seen in ancient permafrost samples. Climate change is altering the dormancy and reactivation patterns of microbial spores, potentially increasing the risk of crop diseases. Advances in nanotechnology are being used to develop coatings that can disrupt spore formation in pathogenic microbes. Genome editing (CRISPR) is being explored to control sporulation in beneficial microbes for agricultural applications. Deep-sea and space exploration studies are examining microbial spores' ability to survive in extraterrestrial environments.

Biofilm Formation: Strength in Numbers

Microorganisms often form biofilms which are structured communities encased in a self-produced extracellular matrix. These biofilms protect microbes from environmental stressors, such as desiccation, UV radiation, and antibiotics. In agriculture, biofilms enhance microbial survival on plant roots and leaf surfaces. Biofilms are now known to facilitate horizontal gene transfer among members, enhancing genetic diversity and adaptability, by enabling the spread of antibiotic resistance and metabolic genes. AI-driven imaging techniques are being used to study biofilm formation in real time. Research is underway to develop biofilm inhibitors to combat antibiotic-resistant infections in healthcare settings. Biofilm engineering is being explored for wastewater treatment and bioremediation applications.

Horizontal Gene Transfer (HGT): Sharing to care

Microorganisms in agricultural soils often engage in HGT, exchanging genetic material that confers traits like antibiotic resistance, pesticide degradation, and nutrient utilization. HGT is a major driver of antibiotic resistance and metabolic versatility. Enables rapid adaptation to environmental changes, such as antibiotic exposure or nutrient scarcity.

Three primary mechanisms drive HGT:

- **Transformation:** A cell takes up free DNA from the environment.
- **Transduction:** A virus (bacteriophage) transfers DNA between cells.

- **Conjugation:** DNA is transferred directly from one cell to another through physical contact.

Mobile genetic elements (e.g., plasmids, transposons) are increasingly recognized as key players in HGT, even across distantly related species. The use of manure and wastewater in agriculture is contributing to the spread of antibiotic resistance genes through HGT. Scientists nowadays are developing gene-editing tools to control HGT and prevent the spread of antibiotic resistance genes. Environmental DNA (eDNA) analysis is being used to track HGT in real-time in different ecosystems. Bacteriophage therapy is being explored to target harmful gene transfer in microbial communities.

Syntrophy and Metabolic Cooperation

Syntrophy (also called cross-feeding) is a type of symbiosis where two or more microbial species work together to degrade complex substrates or survive in nutrient-limited environments. Microorganisms engage in metabolic partnerships where one species' waste products serve as nutrients for another. Many microorganisms form mutualistic relationships with plants, enhancing their survival. For example, nitrogen-fixing bacteria (e.g., *Rhizobium*) and mycorrhizal fungi improve plant nutrient uptake in exchange for carbohydrates. Methanogenic archaea and sulfate-reducing bacteria cooperate to degrade organic matter in anaerobic environments. Synthetic microbial consortia are being designed to enhance bioremediation and bioenergy production. AI-based metabolic modeling is being used to optimize microbial partnerships for industrial applications.

Utilization of Alternative Energy Sources

Some microbes can survive in nutrient-poor environments by oxidizing inorganic compounds like sulfur, iron, and nitrogen. Anaerobic respiration and fermentation also help microbes endure low-oxygen conditions.

Production of Protective Compounds

Microbes produce osmoprotectants such as trehalose and glycine betaine to combat dehydration. Some also secrete antibiotics to outcompete other microbes.

CRISPR-Cas Systems: The Microbial Immune System

Microbes use CRISPR-Cas systems (Clustered Regularly Interspaced Short Palindromic Repeats and CRISPR-associated proteins) to defend against viruses and plasmids by targeting specific DNA sequences. This system is now being harnessed for gene editing in biotechnology.

Survival in Extreme Conditions

Microorganisms can sometimes thrive in extreme environments like: halophiles in high-salt conditions, thermophiles in heat, psychrophiles in cold, acidophiles in acidic environments, and alkaliphiles in basic conditions. Their adaptability showcases the vast potential of microbial life.

Modes of Dispersal: How Microorganisms Travel the World

Microbial dispersal methods can be broadly classified into physical methods (airborne, soilborne and waterborne), biological methods (animal vectors, plant-mediated) and anthropogenic methods.

Airborne Dispersal

Microorganisms can travel long distances via aerosols, dust, and water droplets. Fungal spores, such as those from *Aspergillus* and *Penicillium*, and bacterial cells like *Pseudomonas* can be carried by wind. Atmospheric rivers and storms have been shown to transport microbes across continents, influencing global microbial biogeography. Spores of *Bacillus* and *Clostridium* resist UV radiation and desiccation, allowing long-distance aerial dispersal. Airborne pathogen monitoring systems are being developed using machine learning and remote sensing.

Soil and Waterborne Dispersal

Microbes spread through soil erosion, runoff, and irrigation as well as through water film covering the soil particles. *Phytophthora*, a pathogenic fungus, disperses through contaminated water. Raindrops cause soil splash, propelling microbes into the air or relocating them in surface soil. Marine viruses and bacteria are dispersed by ocean currents, contributing to the global "viral shunt" that regulates nutrient cycling. Environmental DNA sequencing is being used to track microbial dispersal in soil and water systems. As an application of this method of dispersion microbial probiotics are being introduced to soil and water ecosystems to enhance bioremediation.

Animal Vectors

Insects, birds, and mammals act as carriers for microorganisms. For example, bees and other pollinators disperse beneficial microbes like *Lactobacillus* and *Bacillus* species, which can enhance plant health. Conversely, insects like aphids and whiteflies spread viral and bacterial pathogens

Microbial Hitchhiking

Microbes attach to larger particles, such as dust or microplastics, facilitating long-distance dispersal. Studies suggest that microplastics serve as vehicles for antibiotic-resistant bacteria.

Plant-Mediated Dispersal

Microorganisms can move within and between plants through root exudates, vascular systems, and pollen. In rhizosphere interactions, root exudates (sugars, amino acids) attract microbial colonizers, facilitating movement via chemotaxis. Another method of plant mediated dispersal is through seed dispersal. Endophytic bacteria and fungi are dispersed when seeds germinate, influencing plant-microbe symbiosis

Human Activities: Accelerating Microbial Dispersal

Plowing and tillage disturb microbial communities by redistributing soil bacteria and fungi, while the application of compost and manure introduces diverse microbial species, enriching soil biodiversity. Irrigation and flooding further influence microbial distribution by mobilizing bacteria through water flow, reshaping microbial populations across different regions. Additionally, the global trade of agricultural products has facilitated the spread of invasive pathogens, such as *Fusarium oxysporum*, the fungus responsible for Panama disease in banana plantations, posing significant threats to crop health and food security.

Industrial and Urban Activities

Construction and mining activities disrupt soil structure, bringing deep-seated microbes to the surface and altering their natural habitats. The application of wastewater and biosolids further impacts microbial communities by introducing industrial and human-associated microbes into the soil, potentially affecting ecosystem balance. Additionally, genetically engineered microbes are increasingly being introduced as biofertilizers or biocontrol agents, enhancing plant growth and soil health while influencing microbial interactions in agricultural environments.

Conclusion

Microorganisms are not merely passive inhabitants of ecosystems; they are dynamic, adaptive, and deeply influential. Their resilience and dispersal mechanisms shape biodiversity, influence agriculture, and impact human health. As climate change and human activities continue to reshape microbial landscapes, understanding their survival and dispersal strategies is crucial. By harnessing microbial potential, we can develop sustainable solutions in medicine, agriculture,



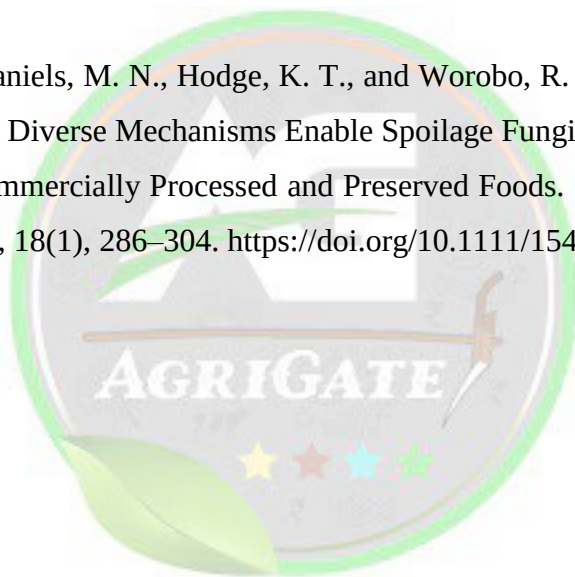
and environmental conservation, ensuring that these unseen architects continue to support life on Earth.

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DIGITAL UPRISING: ONLINE ACTIVISM AND ITS INFLUENCE ON ENVIRONMENTAL MOVEMENTS

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Abstract

A new era of online engagement that cuts beyond social and geographic divides has emerged as a result of the digital revolution, fundamentally changing the landscape of environmental activism. With an emphasis on the dynamic interaction between virtual involvement and real-world impact, this paper explores how online activism contributes to practical environmental change. Environmental movements have gained fresh traction through blogs, internet campaigns, and social media platforms, which have made it easier to mobilize support, raise awareness, and influence institutions. Campaigns like #FridaysForFuture and #SaveTheAmazon show how digital storytelling and hashtags can inspire global audiences and shape public discourse. Despite concerns about “slacktivism” and the temporary nature of online engagement, online activism has significant potential when combined with on-ground strategies. This paper advocates for a hybrid approach to activism that balances digital outreach with sustainable real-world impact.

Keywords: Online Activism, Environmental Change, Social Media, Digital Communities, Environmental Awareness, Real-World Impact.

Introduction

The emergence of digital communication tools in the twenty-first century has had a profound impact on the field of environmental and social action. Online platforms have become effective advocacy tools that allow activists to get beyond the conventional boundaries of accessibility, geography, and class. This shift has led to the emergence of what academics refer



to as "digital" or "online" activism, which uses social media and the internet to mobilize public opinion, increase awareness, and start tangible change (Vegh, 2003; Joyce, 2010).

Digital platforms have given environmental advocacy, in particular, a fresh lease on life. The need for coordinated action is becoming more pressing as ecological issues including pollution, deforestation, climate change, and water scarcity continue to jeopardize global sustainability. Online activism is a powerful force in this regard, enabling narrative, community building, and real-time information sharing across national and cultural borders. Examples of how digital movements may get international attention, put pressure on decision-makers, and spur on-the-ground mobilization are Fridays for Future and Save the Amazon (Fisher & Nasrin, 2021).

With an emphasis on the relationship between virtual engagement and real-world environmental results, the current study explores the impact of online activism on environmental movements. It looks at how blogs, digital storytelling, social media platforms, and well-planned hashtag campaigns can increase public awareness of environmental issues and inspire action. It also examines the tactics used by effective digital campaigns, including consistent message, cooperation with grassroots groups, and the use of visual media, and how these support environmental advocacy (Wolbring & Gill, 2023; Pandit et al., 2025).

The Rise of Digital Environmental Movements

With more than 5 billion individuals online, Internet platforms present activists with a never-before-seen chance to organize audiences, build networks, and start conversations. Responding quickly to pressing environmental challenges is made possible by online action. Globally, hashtag initiatives like #ClimateStrike and #ActOnClimate have been successful in bringing environmental issues into the public eye and into the legislative branch.

Because digital movements reduce entry barriers, they have a particularly significant influence. Joining a campaign, sharing information, or even planning local protests is possible for anybody with internet access. Digital campaigns' accessibility and visibility help provide issues that may have otherwise stayed marginalized more traction, claim Fisher and Nasrin (2021).

Digital Storytelling and Public Mobilization

One effective tactic in digital activism is storytelling. Environmental issues become more accessible and emotionally compelling when they are humanized through videos, infographics, and personal accounts. Nowadays, social media sites like Twitter, Instagram, and

YouTube play a major role in the emotional engagement of audiences and the dissemination of messages.

Thunberg's weekly school strike grew in popularity thanks to graphics and recurring online content. Millions of people participated in the Fridays for Future movement, which quickly evolved into a global youth-led climate strike (Wahlström et al., 2019).

Case Studies and Analysis

Fridays For Future

Founded by Greta Thunberg, this campaign used Twitter, Instagram, and YouTube to mobilize millions for climate strikes worldwide. The campaign succeeded in influencing public discourse and policymaking in several European countries.

Key Success Factors

- Strong narrative and personal storytelling.
- Visual media and regular content updates.
- Decentralized, youth-led mobilization

Save The Amazon

This movement gained traction during the 2019 Amazon fires. It spread awareness through infographics, satellite images, and emotional appeals.

Limitations Noted:

- Short-term engagement.
- Limited follow-through in terms of policy influence.

Break Free From Plastic

This campaign combined digital tools with on-ground clean-up drives and lobbying efforts. It successfully pushed for corporate accountability in plastic pollution.

Success Factors

Collaboration with NGOs and grassroots organizations.

Transparent, data-driven communication.

Offline activities tied closely with online messaging.

Challenges and Limitations of Online Activism

Online activism has drawbacks despite its potential. 'Slacktivism', a type of activism that involves little work, such sharing a post or altering a profile photo, is criticized for frequently not

resulting in significant offline action (Morozov, 2009). Digital channels are also vulnerable to performative activism, echo chambers, and false information.

Furthermore, campaigns can lose steam fast due to the transient nature of internet trends. This calls into question long-term effects and sustainability. Because of the speed at which content is consumed on sites like Twitter and TikTok, consumers may experience digital weariness and lose interest.

Hybrid Engagement: Integrating Digital and Traditional Activism

This study suggests a hybrid activism paradigm to overcome these drawbacks. Today's successful environmental campaigns effectively integrate internet resources with grassroots initiatives. Digital campaigns, for example, can be used to raise awareness and recruit new members, but in order to have a lasting effect, actual protests, workshops, and policy discussions are necessary. Campaigns can develop layered methods that maintain attention and promote active engagement by combining digital storytelling with conventional modes of mobilization. Such collaboration promotes deeper engagement, increases credibility, and increases trust.

Conclusion

Unquestionably, online activism has changed how environmental movements function. It has facilitated global communities around environmental problems, democratized access, and expedited communication. However, systemic change cannot be achieved with digital technologies alone. Online activism's full potential is realized when it is combined with offline initiatives that guarantee sustainability, accountability, and tangible outcomes. The dual nature of digital engagement—its advantages and disadvantages—must be understood by stakeholders, legislators, and activists in order to develop tactics that strike a balance between online presence and measurable results. Our strategy for environmental advocacy must change along with the digital landscape.

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SOIL EROSION AND IT'S DESTRUCTIVE PHENOMENON

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Introduction

The permissible limit of soil loss is generally considered to be 12 tons per hectare per year. But, the national average soil loss in India is estimated to be 21 tonnes per hectare per year, which is higher than the permissible limit of 12 t/ha/year. Approximately 0.666 grams of soil are lost every second per hectare in India. 30% of India's landmass is experiencing "minor" soil erosion, 3% facing "catastrophic" topsoil loss. Catastrophic erosion is defined as over 100 tonnes of soil lost per hectare annually. Brahmaputra Valley in Assam is identified as the country's biggest hotspot for soil erosion. It is estimated that by 2050 around 90 percent of the Earth's soils could be degraded. The loss of soil due to shifting agriculture (podo cultivation) is no less pronounced in India especially in north-eastern region. It has been estimated that more than 1.5 Mha of forest land is cleared for shifting agriculture every year. The total area affected by shifting cultivation is estimated to be 4.5 Mha. Shifting agriculture locally known as "jhumming".

Types of erosion

1. Natural Erosion or Geological Erosion - Erosion is termed as natural or geological erosion if the rate of soil loss does not exceed the rate of soil formation.
2. Accelerated Erosion - Once the rate of soil loss exceeds the rate of soil formation this type erosion is called accelerated erosion. The accelerated erosion is manmade mainly resulting from faulty agricultural practices and deforestation.

WIND EROSION

The wind erosion process may be divided into three simple but distinct phases

i.e detachment, transportation and deposition.

1) Detachment: The lifting and abrasive action of the wind results in detachment of tiny soil grains from the aggregates or clods of which these are a part.

2) Transportation: Movement of detached particles takes place mainly by three processes saliation, suspension and surface creep.

i. Saltation- Movement of soil particles in a series of jumps or bounces. Soil particles having sizes ranging from 0.05 to 0.5 mm generally move in this process.

ii. Suspension- Suspension represents the floating of small sized particles in the air stream. Size of the soil particles In suspension process is less than 0.2mm in diameter.

iii. Surface creep-Rolling of coarse grains along the ground surface is called surface creep. Size of the soil particles in the surface creep is **more than 0.5 mm**.

3) Finally the material is eventually deposited in areas where the wind's velocity decreases or encounters an obstacle.

WATER EROSION

Splash Erosion:

Splash erosion or raindrop impact represents the first stage in the erosion process. Rain drops behave as little bombs when falling on exposed or bare soil, dispersing the soil aggregates and displacing the detached soil particles. The splashed particles may rise as high as 0.7 m above the ground and move horizontally to a distance of 1.5 m.

Sheet Erosion:

Sheet erosion is the uniform removal of soil layers from the sloping lands (skimming of the cream). The top fertile soil layer is washed away from the arable lands. Since a uniform layer of soil is removed, this type of soil erosion mostly goes unnoticed by the farmers.

Rill Erosion:

Rill erosion is the most common form of soil erosion by water. When the runoff water gets concentrated due to isolated patches of vegetation or rockpieces, the silt-laden runoff forms well-defined small ephemeral channels called rills. The rills so formed from one storm are often obliterated before the next storm by simple tillage practices.

Gully Erosion:

Gully erosion is an advanced stage of rill erosion where surface channels have eroded to the point where these cannot be obliterated by tillage operations.

SOIL CONSERVATION PRACTICES

Soil conservation refers to the practices and strategies implemented to prevent soil erosion, maintain soil fertility, and ensure a healthy soil ecosystem. It's about managing the soil to prevent its destruction or degradation.

CONSERVATION TILLAGE

Conservation tillage is an agro management method that seeks to reduce the intensity or frequency of tillage operations in order to realize both environmental and economic benefits. It involves the planting, growing and harvesting of crops with limited disturbance to the soil surface. Two types 1) No tillage 2) Minimum tillage

CHECK DAMS

A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the velocity of flow. Reduced runoff velocity reduces erosion and gully in the channel and allows sediments to settle out. A check dam may be built from stone, sandbags filled with pea gravel, or logs.

VEGETATIVE BARRIERS

Vegetative barrier is a strip planted with a grass or shrub that runs across the slope. It slows down water flowing down the slope and catches the sediment that has been eroded uphill. Over time, soil may build up behind the strip.

COVER CROPS

Cover crops are close-growing crops such as grasses, legumes or small grains that are grown primarily to provide seasonal protection against erosion and for soil improvement.

TERRACING

Is a method of controlling the soil erosion in which broad channels are constructed across the slope of land in humid areas. It decreases the length of hillside slope, prevents the formation of gullies and allows sediment to settle from runoff water.

CONTOUR BUNDING

Contour bunding is a proven sustainable land management practice for marginal, sloping, and hilly land where the soil productivity is very low. Over generations, this technology has been used successfully to control soil erosion, promote water retention, and increase crop production. These are 1.5-2 m wide each bank across the slope or along the contours to form water storage area on their upslope side, act as permanent buffers in a strip cropping system being planted with



grasses or trees, break-up a slope into segments so that overland flow is not generated so as to conserve moisture and harvest rainwater.

BIOPLASTIC COMPOSTING: A SUSTAINABLE APPROACH

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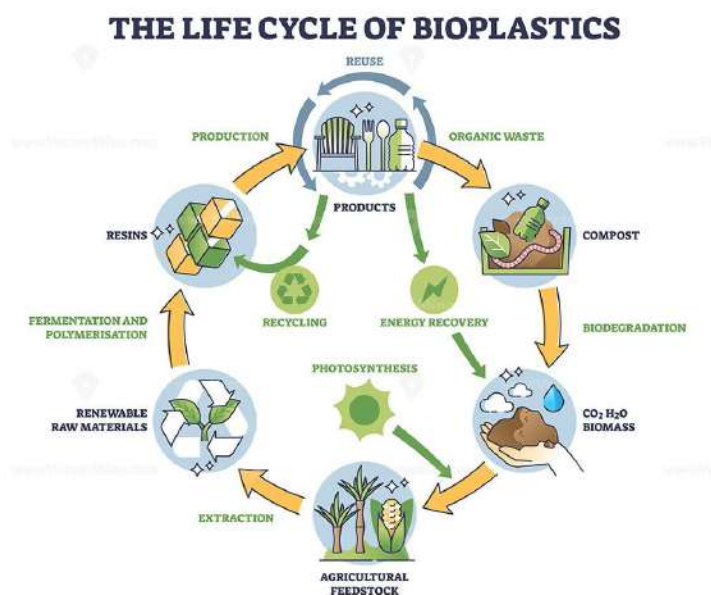
Introduction

Plastic pollution remains a pressing global challenge, prompting a shift towards more sustainable materials, notably bioplastics —polymers derived wholly or partially from renewable bio-based feedstocks and/or designed for biodegradability. Disposal pathways for bio-plastics, especially composting, hold the promise of circular resource use, yet practical implementation is fraught with both technological and environmental complexities



Composting is considered more environmentally friendly and cost-effective than recycling or incineration. Specific microorganisms, such as *Pseudomonaceae*, *Comamonadaceae*, *Erythrobacteraceae*, *Streptomyetaceae* and enzymes, such as N-acetyl--glucosaminidase, esterase, -glucosidase, acid phosphatase, alkaline, and phosphohydrolase, are involved in the degradation and microbial decomposition of bioplastics. Specifically, enzymatic decomposition has been regarded as a means of minimizing environmental pollution.

Microbiological degradation of bioplastics, particularly microbial enzymatic catalysis, has drawn attention as a means of reducing the amount of pollution in the environment. The process of composting involves decomposing organic matter and turning it into humus, which can be used to strengthen soil structure and its fertility rate. Bioplastic waste is typically disposed of in landfills, followed by recycling, incineration, and composting



. In contrast, landfilling produces greenhouse gases and creates environmental concerns. Landfilling not only produces greenhouse gases but also occupies and contaminates future agricultural land. Therefore, composting would be a more profitable and desirable method for disposing of bioplastic waste. As a cost-effective and safe waste management solution, composting technology is being adopted by several industries.

Compostable polymers are being developed as environmentally friendly alternatives, especially if they can be recycled organically and derived from renewable resources. Using lifecycle assessment techniques, ASTM D7075 and ISO 14000 have developed standards to evaluate biobased products and their environmental performance. However, only some of the biopolymers are listed as compostable materials by ASTM. In order for a polymer to be considered compostable, it must convert 90% of its carbon content to carbon dioxide in accordance with ASTM International (D5338). An ASTM International (D5338) polymer can only be considered compostable if 90% of its carbon content is converted into carbon dioxide.

Types of Bioplastics

Starch-Based Bioplastic

Biopolymers made from starch are becoming increasingly popular due to their abundant availability, renewability, low-cost, and biodegradability. Starch is regarded as a promising raw material for biopolymer production. After polylactic acid (PLA), starch-based plastics accounted for the second-highest share of the with total bioplastics production. There are two types of polymers involved in its composition: linear amylose and branched amylopectin. An important feature is their elasticity, which is provided by linear amylose, while amylopectin has a branched structure that controls tensile strength and elongation. Among the most promising biopolymers for producing edible films, starch is particularly popular because of its affordability.

PLA-Based Bioplastic

Polylactic acid is a commercial biodegradable thermoplastic based on lactic acid also called polylactide or PLA (also known as polylactic acid, lactic acid polymer). The most widely used biodegradable aliphatic polyester, PLA is a thermoplastic that is aliphatic non-cyclic, non-aromatic, derived from lactic acid and lactide, and formed by polymerizing sugars obtained from various agricultural biomass sources. Polylactides are developed for degradable packaging materials, and polylactide decomposes within three weeks in industrial composting processes. Polylactide is the first synthetic polymer to be synthesized from renewable resources. Polylactic acid exhibits a number of desirable characteristics, including being easy to fabricate, biocompatible, biodegradable, non-toxic, and having better thermal properties. When polylactic acid biodegrades, it releases water, CO₂, and decomposed organic matter that green plants are able to utilize, which reduces greenhouse gas emissions. Additionally, when oxygen is added to polylactic acid, no toxic intermediates or byproducts are produced. In comparison with other synthetic polymers, polylactic acid emits relatively fewer greenhouse gases.

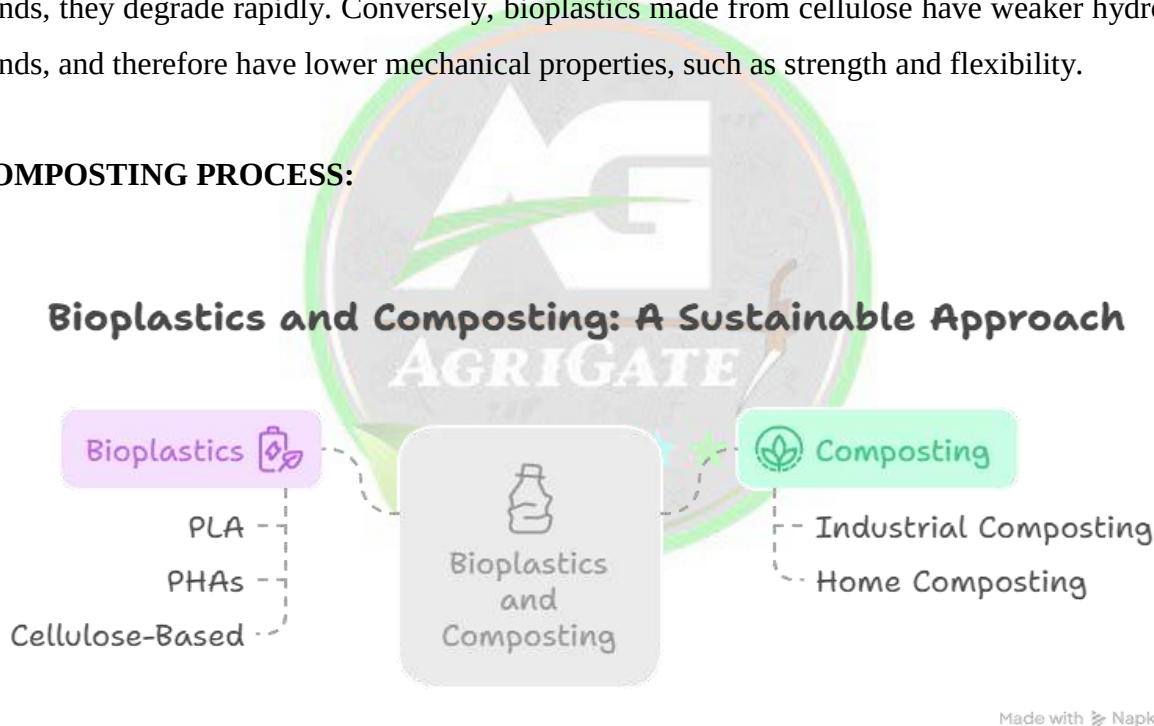
PHAs-Based Bioplastic

Several types of microalgae produce PHAs, which are biodegradable biopolymers. In nutrient-limited environments, diverse prokaryotic microbes produce PHAs for carbon storage. In bioplastics, PHAs have not been widely applied, and this may be due to their high production and recovery costs. Scientists are searching for cost effective feedstocks to replace PHA. Approximately 90 percent of the microbes that degrade PHAs also breakdown starch as the biodegradation pathways are similar.

Cellulose-Based Bioplastic

A variety of biomass can be used to produce cellulose, including wood, seed fibers, bast fibers, grass, marine animals (tunicates), algae, fungi, invertebrates, and bacteria. Additionally, acetic acid bacteria can synthesize cellulose in addition to higher plants. Cellulose consists of linear chains with glycosidic bonds that join a few hundred to more than ten thousand glucose units. Although starch and cellulose have the same monomer unit, they differ in how their polymeric chains are oriented. In recent years, cellulose-based biopolymers have gained attention due to their strength, stiffness, high durability, and biodegradability. In addition to being low-density, low-price, and nonabrasive, cellulose-based reinforced composites are also non-abrasive. As cellulose-based bioplastics contain distant tenuous molecules with weak hydrogen bonds, they degrade rapidly. Conversely, bioplastics made from cellulose have weaker hydrogen bonds, and therefore have lower mechanical properties, such as strength and flexibility.

COMPOSTING PROCESS:



In the context of bioplastics, **aerobic composting plays a critical role** in ensuring that these materials break down as intended. While many people assume that anything labelled "biodegradable" or "compostable" will naturally disappear in a backyard compost bin, the reality is more complex. **Not all bioplastics are created equal**, and their ability to decompose depends heavily on the conditions in which they are processed.

Bioplastics	Origin	Compostability	Typical Products	Biodegradation Rate
Starch-based	Cassava, corn	Home & industrial	Bags, films	Fast (weeks) at optimal
PLA	Corn, sugarcane	Industrial only	Cutlery, cups	Slow unless >55°C & wet
PHA	Microbial	Home & industrial	Packaging, mulch	Rapid in compost/soil
Chitin-based	Shellfish waste	Under study	Packaging, films	Fast; promising results

PLA (Polylactic acid) :

PLA is one of the most widely used bioplastics, commonly found in compostable cups, cutlery, food containers, and packaging films. Despite being made from renewable resources like corn starch or sugarcane, PLA has a relatively high melting point and crystalline structure, which makes it resistant to breakdown in cool or variable environments. As a result, PLA and many other bioplastics require industrial composting conditions—specifically, thermophilic environments where temperatures regularly exceed **55°C (131°F)** for extended periods.

Industrial composting

Industrial composting facilities are equipped to provide these conditions through careful management of airflow, moisture, and carbon-to-nitrogen ratios. They can maintain steady heat, ensuring that microbial communities responsible for decomposition remain active and effective. Under these controlled settings, PLA products can break down in as little as **60 to 90 days**, depending on the specific material and process.

Home composting:

Home composting systems—such as backyard compost piles or bins—are typically less regulated. They often fluctuate in temperature, receive inconsistent aeration, and may lack the volume or diversity of materials needed to sustain high microbial activity. As a result, bioplastics

like PLA **may take years to degrade at home, if they break down at all**, leading to frustration and confusion for environmentally conscious consumer.

This discrepancy highlights a key challenge in the bioplastics landscape: matching the right material with the right disposal system. Without access to industrial composting facilities—or clear guidance on how to properly dispose of compostable plastics—many bioplastic items end up in landfills or contaminate recycling streams, undermining their environmental benefits.

Therefore, for compostable bioplastics to fulfill their potential, it is essential to invest not only in better infrastructure and collection systems but also in education and labeling that clearly distinguish between industrial and home compostability. Only then can we ensure that these materials are managed in ways that truly support sustainability goals.

Parameter	Industrial Composting	Home Composting
Temperature	55–60°C	25–40°C
Retention Time	8–12 weeks (typical)	Variable (months)
Feedstock Control	High	Low
Biodegradation Rate	Faster (esp. for PLA)	Slower, incomplete
Regulatory Standards	EN 13432, EN 14995	None or local

Key Standard

- **EN 14995:** For non-packaging compostable plastics.
- **EN 13432:** For packaging, requires 90% conversion to CO₂ within 6 months in an industrial composting facility .
- **ASTM D6400** (United States): This is the American equivalent. Like EN 13432, it requires materials to biodegrade and disintegrate within a specific timeframe under industrial conditions, and it ensures that the compost remains safe for plants and soil life.

Home composting certifications (e.g., TÜV OK compost HOME): These are stricter, because the conditions in home compost bins are cooler and less consistent. Materials certified for home composting must be able to break down at lower temperatures, usually over a longer period, without requiring the high heat of industrial systems.

Degradation Kinetics and Environmental Factors

Rate and Extent of Biodegradation

The breakdown of bioplastics during composting is governed by a combination of microbiological action (enzymes), polymer structure, and environmental parameters such as temperature, moisture, and compost matrix composition .

Bioplastic Types Comparison

Characteristic	Starch Film (Cassava)	PLA Rigid (Spoons)	Mater-Bi® Films
 Temperature Range	30–40°C	37–58°C	37–58°C
 Degradation Rate (k)	0.12–0.14	0.002–0.014	0.085–0.17
 Time for 90% Degradation	45–57 days (home)	2–3 years (suboptimal)	60 days (optimal)

Made with  Napkin

Environmental Influences

- **Temperature:** Crucial for hydrolysis and enzymatic activity; PLA requires >55°C for effective breakdown .
- **Moisture:** Low humidity slows biodegradation; compost must remain moist for optimal microbial function .
- **Physical Form:** Films degrade faster than rigid objects (e.g., cutlery) due to higher surface area and porosity .
- **Additives and Blends:** Materials like chitin or organoclay can tune mechanical and degradation properties

Operational Challenges in Waste Management

Integrating Bioplastics with Organic Waste

Despite certification, integration of bioplastics into existing composting facilities is not straightforward . Common challenges include:

- **Pre-treatment Losses:** Size-based screening often discards bioplastics with plastics, leading to loss of organic matter .
- **Inadequate Degradation:** Some “compostable” products persist under real-world conditions, especially in home composting or anaerobic digestion .
- **Cross-Contamination:** Bioplastics can pollute traditional plastics recycling streams due to their indistinguishability .
- **Microplastics Formation:** Incomplete breakdown—particular in rigid bioplastics—can yield microplastics in the compost undersieve fraction

Environmental Impacts

Greenhouse Gas Emissions

Composting bioplastics can lead to both savings and emissions depending on substituted materials and system management:

- **GHG Savings:** Use of compost as a peat substitute can yield significant reductions—up to -900 kg CO₂-eq/tonne wet waste .
- **Net Load:** Poorly managed systems or non-optimal composting can result in a net GHG emissions load (up to +300 kg CO₂-eq/tonne) .
- **Incomplete Documentation:** Often, the fate of composted bioplastics is hard to track along with savings or environmental trade-offs .

Conclusion

Bioplastic composting offers a potential avenue for sustainable waste management and resource recovery, but realizing its benefits depends on matching material properties with composting technology, robust certification, and agility in waste management systems. Further research and policy development must focus on resolving the disconnect between laboratory standards and field realities, integrating bioplastics more seamlessly with organic recycling, and actualizing their environmental promise through holistic systems thinking .

SCIENTIFIC INSIGHTS INTO RICE QUALITY PARAMETERS

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Introduction

Rice quality goes far beyond mere appearance — it determines cooking behavior, nutritional value, and ultimately, consumer satisfaction. In an era where both domestic and international markets demand superior quality grains, the ability to evaluate rice accurately has become essential. Yet, quality cannot be judged by sight or taste alone. It must be measured using standard, science-based methods. This article presents a comprehensive overview of the most important rice quality parameters, such as grain size and shape, chalkiness, milling recovery, cooking characteristics, and nutrient content. For each parameter, the article explains what it represents, why it matters, and how it is analyzed using practical and widely accepted procedures. Whether it is the iodine-binding method to assess amylose content, the alkali spreading value test for gelatinization temperature, or protein estimation through chemical analysis, these techniques form the backbone of quality evaluation in rice research, breeding, processing, and marketing. By translating technical methods into an easy-to-understand format, this article aims to bridge the gap between science and application — helping farmers, students, extension workers, and agri-professionals appreciate the value of each grain beyond yield.

Rice is one of the most essential staple crops in the world, feeding more than half of the global population. In many Asian countries, including India, rice is not just a dietary staple — it is deeply tied to culture, livelihood, and food security. As demand for better food quality rises,

the focus is shifting beyond just yield. Today, grain quality is a crucial factor that influences consumer acceptance, market price, processing efficiency, and even export potential. But what does rice "quality" actually mean? It is not a single trait, but a combination of several important characteristics. These include physical traits like grain length, shape, and chalkiness; milling quality such as head rice recovery; cooking and eating quality including amylose content, gelatinization temperature, aroma, and texture; and nutritional value like protein and mineral content. Each trait contributes to the overall desirability of a rice variety and determines its suitability for specific consumer groups or market segments. In this context, scientific analysis of rice quality parameters has become essential — especially in plant breeding programs. Breeders no longer aim for high-yielding varieties alone. Modern breeding efforts focus on developing rice varieties that combine high productivity with superior grain quality. To achieve this, quality traits must be **measured accurately and consistently** using standardized laboratory procedures.

These analyses help breeders:

- Screen parental lines for desirable traits,
- Evaluate breeding populations,
- Select high-quality lines for advancement, and
- Release varieties that meet both consumer and industry standards.

By understanding **what each quality trait means** and **how it is measured**, researchers, students, and even farmers can better appreciate the science behind varietal development. This article provides a simplified overview of the most important rice quality parameters, along with the commonly used methods for their analysis, to help bridge the gap between field-level interest and laboratory-based evaluation.

Types of Rice Quality

Rice quality is assessed based on several factors that can be broadly categorized into:

1. Physical Quality:

- **Grain Size and Shape:** Classified into long, medium, and short grain types, with specific shape indices defining each type.

Scale	Length in mm	Size category
1	≥ 3.0	Slender
5	2.1 to 3.0	Medium
9	≤ 2.0	Bold

Based on shape:

- **Grain Color:** Varies from white, Light brown, Variegated brown, Dark brown, black, Light red, Red, Variegated purple, Purple, Dark purple, depending on the variety and processing.
- **Chalkiness:** Degree of chalkiness describes the milled sample rice for (a) white core (b) white belly, and (c) white back. Chalky white spots often appear in the starchy endosperm. A white chalky region extending to the ventral side's edge and towards the endosperm's center is called a white core. Soft textured, white spots occurring in the middle part on the ventral side (side on which the embryo lies) are called abdominal white or white belly. A long white streak on the dorsal side is called the white back.

State	Kernel	Note
Absent or very small	None	1
Small	<25%	3
Medium	26-50%	5
Large	51-75%	7
Fully chalky	>75%	9

- **Milling Quality:** Milling yield is the estimate of the quantity of total milled rice and head rice that can be produced from a unit of rough rice. It is generally expressed as a percentage. The milling process usually involves five key operations: (i) Firstly, clean the rough rice to remove unwanted matter (such as leaves, rice stems, and other foreign matter), (ii) Secondly, dehulling to remove the hulls, (iii) Thirdly, cleaning the BR to

$$\bullet \text{ Brown rice (BR) (\%)} = \frac{\text{Weight of brown rice}}{\text{Weight of rough rice}} \times 100$$

$$\bullet \text{ Hull (\%)} = \frac{\text{Weight of hulls}}{\text{Weight of rough rice}} \times 100$$

$$\bullet \text{ Total milled rice (\%)} = \frac{\text{Weight of total milled rice}}{\text{Weight of rough rice}} \times 100$$

$$\bullet \text{ Head rice (\%)} = \frac{\text{Weight of head rice}}{\text{Weight of rough rice}} \times 100$$

$$\bullet \text{ Degree of milling (\%)} = \frac{\text{Weight of total milled rice}}{\text{Weight of brown rice}} \times 100$$

remove the hulls, (iv) Fourthly, polishing the BR, (v) Finally, separate broken kernels from the whole grains.

Milling yield calculations: The percentage of milling quality of rough rice can be calculated by the following formulas:

2. Chemical Quality:

Amylose Content: Glutinous rice has waxy grains, while non-glutinous rice is non-waxy to transparent, varying with amylose content. To determine amylose content, the simplified Juliano (1971) method is used. Twenty whole milled rice grains are ground (sieve mesh size 60). 100 mg of rice powder is placed in a 100 ml flask with 1 ml of 95% ethanol and 9 ml of 1N NaOH, then heated in a boiling water bath to gelatinize starch. After cooling for an hour, distilled water is added, and the solution is mixed. Standard varieties (low, intermediate, high amylose) serve as checks. Five ml of starch solution is transferred to another 100 ml flask with 1 ml of 1N acetic acid, 2 ml of iodine solution (0.2 g iodine, 2 g potassium iodide in 100 ml water), and topped with distilled water. After standing for 20 minutes, absorbance at 620 nm is measured using a spectrophotometer. Amylose content is calculated using a conversion factor and expressed on a dry weight basis. Moisture determination is unnecessary if lab humidity and temperature are controlled.

State	Content of amylose	Note
Very low	3-9%	1
Low	10-19%	3
Medium	20-25%	5
High	26-30%	7
Very high	>30%	9

Protein Content: Total protein content of the grains can be estimated by the method given by Lowery *et al.*, (1951).

Reagents:

- 2% Na₂CO₃ in distilled water (reagent A).
- 0.5% CuSO₄, H₂O in 1% sodium potassium tartarate or sodium citrate (reagent B).
- 50ml of reagent (A) was mixed with 1ml of reagent (B) (reagent C).
- Folin reagent.

Extraction:

The residue left after 80% ethanol extraction from carbohydrate analysis was hydrolyzed in 5.0ml of 1N NaOH for overnight and then centrifuged at 4000rpm for 20minutes. Supernatant was kept aside and the residue again hydrolyzed with 5.0ml 1N NaOH for 1 hour and centrifuged. Both the supernatants were pooled and volume was made to 10ml. The total protein was estimated in the supernatant by folin reagent.

Procedure:

0.5ml aliquot was taken in test tube mixed with 5.0ml of reagent (C) and allowed to stand for 10minutes, thereafter, 0.5ml of folin reagent was added with instant mixing. After 30minutes O.D. was read at 750nm through Spectronic 20 against reagent blank. A standard curve was prepared with graded concentration of bovine serum albumin. Test tubes were given water bath treatment for 8minutes. Finally cooled at room temperature and O.D. was measured at 630nm.

Aroma Compounds: Determine the fragrance of aromatic rice varieties (e.g., 2-acetyl-1-pyrroline in Basmati). The method consists of adding about 15 ml of water to 5g of rice sample in a test tube (200 mm x 35 mm), and soaking for 10 minutes. Cook the sample in the water bath for 15 minutes. Transfer the cooked rice into a petri dish. After cooling, keep it in the refrigerator for 20 minutes. Then the Petri plates are opened and the contents are smelled. The samples possessing the scent, as one could easily feel, produce a sharp and readily recognizable aroma. (DRR, unpublished).

SS: Strongly Scented

MS: Mild Scented

NS: Non-Scented

3. Cooking and Eating Quality:

Gelatinization Temperature: Duplicate sets of six whole milled grains are spaced evenly in transparent plastic boxes (50 mm x 42 mm x 22 mm) containing 10 ml of 1.7% Potassium Hydroxide. The dishes are kept at 27- 30oC for 23 hours undisturbed in an incubator. Standard varieties must be used as checks for high, intermediate, and low gelatinization temperatures. The spreading of kernels noted on a 7-point scale is expressed as the average of six values. Scoring is done as follows:

Alkali Spreading Value / Scale

1. Kernel not affected

2. Kernel swollen
3. Kernel swollen, collar incomplete and narrow
4. Kernel swollen, collar complete and wide
5. Kernel split or segmented, collar complete
6. Kernel dispersed, merging with collar
7. All kernel are dispersed and intermingled

Alkali spreading value/ Scale	Classification	Gelatinization temperature	Note
6-7	High	Low	1
4-5	Medium	Medium	3
3	Low, Medium	High, Medium	5
1-2	Low	High	7

Water Absorption and Swelling Capacity: Affects texture and volume after cooking. Evaluated by measuring Kernel Length before and after cooking.

- **Cooking Time:** Influences convenience and energy use. Evaluated inversely by analysing the Alkali spreading value as in Gelatinization temperature analysis.
- **Texture and Taste:** Evaluated through sensory analysis or instrumental measurements.

4. Nutritional Quality:

- **Vitamin Content:** Evaluates essential vitamins like B1 (thiamine), B2 (riboflavin), B3 (niacin), B6 (pyridoxine), and E (tocopherol) for nutritional quality.

Methods:

- ✓ **HPLC:** Accurate for B-complex and vitamin E.
- ✓ **UV-Vis Spectrophotometry:** Common for thiamine, riboflavin.
- ✓ **Fluorometric Assay:** Sensitive for riboflavin, pyridoxine.
- ✓ **Microbiological Assay:** Measures B vitamins using microorganisms.

- **Minerals:** Mineral estimation in rice is essential for evaluating nutritional value, focusing on key minerals like iron, zinc, magnesium, calcium, and potassium.

Methods:

- ✓ **Atomic Absorption Spectroscopy (AAS):** Sensitive for iron and zinc.
 - ✓ **ICP-MS:** Multi-elemental analysis with high sensitivity.
 - ✓ **X-Ray Fluorescence (XRF):** Rapid, non-destructive screening.
 - ✓ **Flame Photometry:** Used for potassium and sodium estimation.
 - ✓ **Wet Digestion and Titration:** For calcium analysis.
- **Antioxidants:** Antioxidant estimation in rice is crucial for assessing its health benefits, especially in pigmented varieties rich in phenolics, flavonoids, and anthocyanins.

Methods:

- ✓ **DPPH Assay:** Measures free radical scavenging capacity.
- ✓ **ABTS Assay:** Evaluates antioxidant capacity as Trolox equivalent.
- ✓ **FRAP Assay:** Assesses reducing power of antioxidants.
- ✓ **Total Phenolic Content (TPC):** Uses Folin-Ciocalteu reagent.
- ✓ **Total Flavonoid Content (TFC):** Aluminum chloride colorimetric method.
- ✓ **HPLC:** Precise quantification of specific antioxidants.

Importance of Rice Quality Analysis

1. **Consumer Satisfaction:** Ensures the rice meets consumer preferences for taste, aroma, texture, and appearance, driving market demand.
2. **Nutritional Value:** Assesses essential nutrients (like protein, iron, zinc) critical for human health, supporting food security.
3. **Market Value:** High-quality rice commands better prices in both domestic and international markets.
4. **Varietal Improvement:** Helps breeders select superior genotypes with better grain quality traits, aiding in the development of improved rice varieties.
5. **Quality Control:** Ensures compliance with national and international standards, safeguarding public health and maintaining export credibility.

6. **Storage and Processing Efficiency:** Evaluates traits affecting milling, cooking, and storage, reducing post-harvest losses.

Future Aspects of Rice Quality Analysis

1. **Precision Phenotyping:** Advanced imaging, spectroscopy, and machine learning for rapid, accurate assessment of quality traits.
2. **Nutritional Biofortification:** Increased focus on analyzing micronutrient content (iron, zinc) to combat malnutrition.
3. **Non-Destructive Methods:** Adoption of non-invasive techniques (NIR spectroscopy, hyperspectral imaging) for quality analysis.
4. **Consumer-Driven Selection:** Integration of consumer preferences in breeding programs for taste, texture, and aroma.
5. **Climate-Resilient Varieties:** Analysis of rice quality under different environmental conditions to ensure stable quality.
6. **Data-Driven Decision Making:** Use of AI and big data for predictive modeling of quality traits in breeding.
7. **Sustainability Metrics:** Inclusion of environmental impact assessment in quality analysis, promoting eco-friendly rice production.

Conclusion

Rice quality is a complex and vital aspect that influences not only consumer satisfaction but also the economic viability and global competitiveness of rice varieties. It encompasses a wide range of physical, chemical, cooking, and nutritional characteristics — each contributing uniquely to how rice is perceived, processed, and consumed. Accurate measurement and analysis of these quality parameters are indispensable for advancing rice breeding programs. Scientific methods such as grain dimension measurement, amylose content determination, gelatinization temperature testing, and protein analysis provide objective data that guide breeders in selecting superior lines with desirable traits. This ensures that newly developed varieties are not only high-yielding but also meet the diverse demands of consumers, millers, and exporters. Furthermore, quality analysis supports processors and traders by enabling consistent grading, improving market transparency, and adding value throughout the rice supply chain. For farmers, understanding these quality traits and their evaluation can help in choosing the right varieties that fetch better prices and satisfy market standards. In summary, bridging the gap between rice

quality traits and their analytical evaluation empowers all stakeholders — from breeders and scientists to farmers and consumers — to contribute toward producing rice that is nutritious, palatable, and commercially successful. As global food security and consumer preferences evolve, the integration of quality assessment into breeding and production strategies will remain critical to sustaining and enhancing the rice industry worldwide.

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MINIMAL PROCESSING – A MINIMAL WAY FOR BETTER FOOD PROCESSING

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Abstract

In recent years, consumers have been moving towards convenient and healthy alternative food products. The fast-paced lifestyle changed people's preference for fresh-cut fruits and vegetables over raw produce. Minimal processing is a simple way to fulfil the customer's need. It contains minimal operations to produce products from fresh produce. This process will reduce the risk of spoilage and food waste. The market potential of minimally processed foods is huge. Advanced studies are going on to make this process more efficient. This will reduce the daily waste generated in our homes, and only the required quantity will be utilized. This will create a sustainable method for producing fruits and vegetables.

Keywords: Minimal processing, fresh-cut fruits, fresh-cut vegetables, modified atmosphere packaging, edible coating.

1. Introduction

Fruits and vegetables play a prominent role in people's daily diet. Everyone should include a minimum amount of fruits and vegetables in their daily meals to achieve the correct balance of nutrients. Following the COVID-19 pandemic, people have become more conscious of hygiene, safe food, and nutrient-rich diets. They are searching for alternatives to their current food intake, such as functional foods. Similarly, the fast-moving lifestyle has also changed people's food habits. Food items such as ready-to-eat, ready-to-cook, and ready-to-drink are

gaining popularity nowadays. Minimal processing refers to the use of one or more processing methods to convert plant-derived foods into ready-to-cook and ready-to-eat products, preserving the nutritional value and sensory qualities of fresh produce. (Finger *et al.*, 2023). Typically, minimally processed or fresh-cut fruits and vegetables have a shelf life of two days to two weeks, depending on the packaging methods, packaging materials, and storage conditions. Cut fruits are stored for a longer period in cold storage. Food waste and losses should be reduced to achieve the sustainable goal. Minimal processing is a straightforward approach to achieve this.

2. Example of minimally processed fruits and vegetables

Cut fresh fruits: Chunks and slices of watermelon, pineapple core, and sliced fruit, etc.

Cut fresh vegetables: Tomato slices or diced, potato slices, and mixed vegetable salads, etc.



Fig 1. Packaged fresh-cut fruits and vegetables

3. Processing steps

3.1. Harvesting and precooling

Harvesting is the first operation in minimal processing. Properly harvested fruits and vegetables are only required for further processing. After harvesting, precooling is a crucial procedure that helps increase the shelf life of the produce. Processing should be completed within 2 days after harvesting. To remove the field heat from harvested produce, precooling is a crucial step in the process. It is achieved using cool water baths, vacuum cooling, forced air cooling, and ice–water mixture packaging.

3.2. Sorting and cleaning.

It refers to the segregation of fruits and vegetables based on their quality. The segregation process is based on size, shape, and colour. Sorting eliminates produce that cannot be sold or stored due to mechanical damage, insect damage, disease damage, immaturity, over-maturity, or deformity. It ensures only high-quality produce is sent forward for further processing or sale,

thus preventing further contamination and reducing losses. Mechanical sorters and colour sorters are used to sort large amounts of produce. Fruits and vegetables should be thoroughly cleaned before processing if they are covered in dirt, mud, or sand after harvest.

3.3. Peeling/cutting/ shredding

Each fruit and vegetable has a separate operation. Some vegetables, like tomatoes and okra, require cutting into small pieces. Onions and garlic require peeling; cabbage and carrots need to be shredded for packaging. Knives or blades made of stainless steel that are as sharp as feasible must be used for cutting and shredding. Sharp blades are always preferable to dull and blunt ones. Mechanical peeling includes blades and knives. Apart from mechanical peeling, various peeling methods, such as abrasive peeling, lye peeling, flame peeling, and steam peeling, are used to peel specific products.

3.4. Washing/drying

Typically, two washes occur during the process. Before and after cutting fruits and vegetables, washing is necessary. Five to ten litres per kilogram of product should be used before peeling and/or cutting, and three litres per kilogram should be used following these processes. To increase the product's shelf life and sensory quality, preservatives can be added to the washing water to lower bacteria counts and slow down enzymatic activity. The most widely used preservative in minimal processing is chlorine. To increase shelf life, add 100–200 mg/l of chlorine or citric acid to the washing water either before or after peeling. Low pH, high temperature, pure water, and the right contact time can all increase the efficiency of chlorine. At a contact time of 12–13 seconds, a chlorine concentration of 100 mg/l is ideal. After washing, the water should be adequately drained. Drying reduces the product's moisture content and removes cell leakage, which can support microbial growth. Dewatering is done by gentle removal with cheesecloth, centrifugal spin driers, vibrating racks, rotating conveyors, hydro sieves, and forced air drying tunnels (Artés and Allende, 2005).

4. Packaging and storage

Packaging and storage are the most critical operations in minimal processing. Compared to unprocessed or raw products, minimally processed foods are easily subjected to spoilage. Therefore, proper packaging and storage methods are necessary.

4.1 Modified-atmosphere packaging (MAP)

Modified-atmosphere packaging (MAP) is the most effective packaging technique for

pre-cut raw fruits and vegetables. The fundamental idea behind MAP is to use a specific gas mixture with permeable packaging to create a modified atmosphere, either passively or by utilizing active packaging materials. The primary goal is to achieve an ideal gas balance within the package, ensuring that the product's respiration activity is as low as possible while maintaining optimal oxygen and carbon dioxide levels that do not harm the product. Due to their rapid respiration rate, fresh-cut fruits and vegetables quickly deteriorate and discolor when exposed to oxygen.

By altering the composition of the gases (primarily oxygen, carbon dioxide, and nitrogen) surrounding the product within the container, MAP is frequently employed to extend the shelf life of minimally processed foods. This lowers microbial growth and spoiling, delays ripening, and slows down respiration rates. MAP helps preserve the colour, flavour, texture, and nutritional value of minimally processed foods by regulating the environment. Additionally, it lessens weight loss, shrivelling, and moisture loss. MAP can improve food safety by inhibiting the growth of some diseases and rotting organisms. An emerging trend in real-time food safety and quality monitoring is the incorporation of biosensors into Modified Atmosphere Packaging (MAP) systems. Due to their notably high gas permeability, packaging films, including ethylene vinyl acetate blends with low-density polyethylene and oriented polypropylene, have shown potential applications. (Ward, 2016).

4.2 Edible coating

Another potential packaging technique for prolonging the post-harvest storage life of minimally processed goods is the use of edible coatings. When fresh-cut fruits and vegetables are processed, their high moisture content and multiple cut surfaces can lead to browning, microbiological contamination, texture damage, and other issues. Techniques such as modified atmosphere packaging (MAP), sterile water washing, heat treatment, irradiation, film, and coating have been developed to preserve fresh-cut foods. Due to their economic and ecologically beneficial qualities, edible coatings and films have garnered considerable attention in the field of fresh-cut food preservation. A thin layer of edible material that can alter its permeability to water vapour is the basis of the coating or film concept used to preserve food. This achieves barrier lipid oxidation, inhibits microbial decay, prevents browning, lowers mass loss, lowers respiratory rate, and regulates enzyme activity. It is achieved by either edible film or coating (Ma *et al.*, 2024).

Edible films are a thin layer of material around the products. When it comes to edible coatings, the material is typically coated by dipping, spraying, or vacuum impregnation (Fig. 2). Studies on edible coatings have utilized vegetables such as tomatoes and cucumbers, as well as fruits like apples, kiwifruits, strawberries, and cantaloupe. Numerous studies have also examined other substances in edible coatings, such as plasticizers and antimicrobial agents.(Perez-Vazquez *et al.*, 2023).

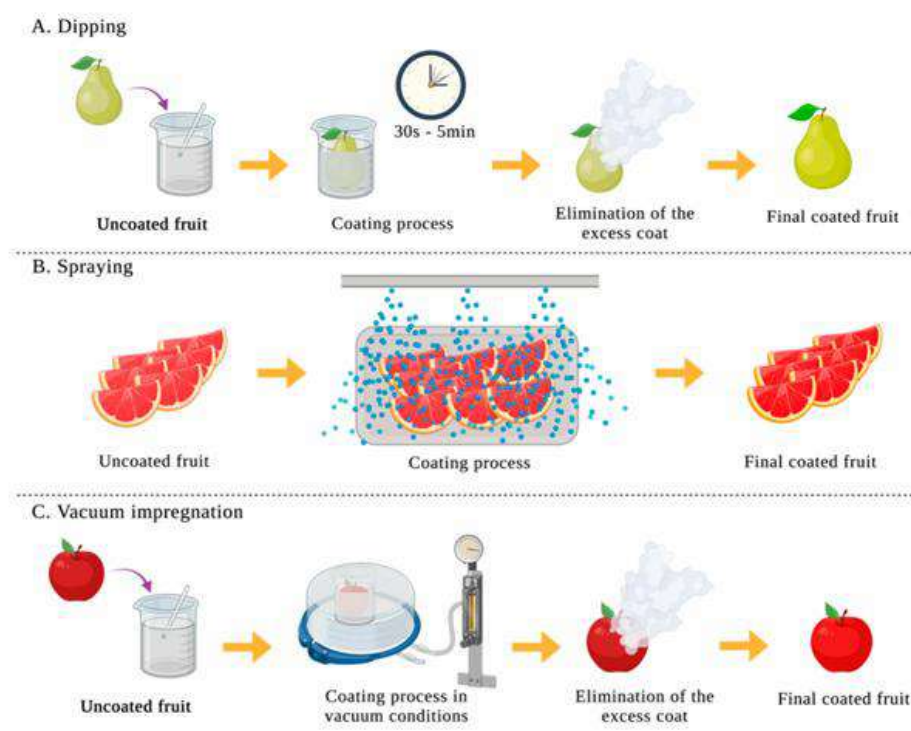


Fig 2. Types of edible coating

5. Recent technologies for fresh-cut produce

To extend the shelf life of fresh-cut fruits and vegetables, continuous research is ongoing. Technologies such as UV treatment, ozone treatment, and pulse light technologies are gaining attention in the minimal processing area. An edible coating, produced from the peels of fruits and vegetables, has yielded good results. These technologies will enhance the process, making it more efficient and sustainable.

Conclusion

Post-harvest waste, generated from fruits and vegetables, should be reduced. Every day, our homes produce more waste from the fruits and vegetables we consume. Minimal processing

is the way to reduce food losses and waste simultaneously. In minimal processing, only the required part and quantity are delivered to the customers. No need to cut means no going to waste. And the processed waste (peel, cut, shred) can be appropriately utilized in one place. In the future, the waste generated from the process plant can be used to make an edible coating material for the same fruits and vegetables that are processed in the same plant. This will make this process more sustainable.

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MODE OF POLLINATION IN CROP PLANTS

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Introduction

Pollination is the pre-fertilization event in which the transfer of pollen grain takes place from the anther of the flower to the stigma of the same plant or different plant, later enabling fertilization and the production of seeds. Pollination is completed only on deposition of pollen grains to the stigma of a flower. In case of self-pollination, the deposition of pollen on the stigma occurs naturally and facilitated by the position of androecium and gynoecium. However, in case of cross-pollination, it requires an agent or vector to transfer or carry the pollen from one flower to the other. Pollinating agents such as insects, (for example beetles or butterflies), birds, bats; water; wind facilitate cross-pollination. On the basis of extent of cross pollination, the crop plants may be categorized into three groups viz., A. Self-pollinated (Autogamous) crops, B. Cross-pollinated (Allogamous) crops and C. Often cross-pollinated (Auto-allogamous) crops. The mode of pollination decides the pollination system in a crop plants. Based on the agent involved, the mode of pollination is classified as below.

I. Abiophily (Abiotic pollination): Involving non-living agents for pollination. This group is further classified into four types viz.,

1. Geophily: Pollination is effected due to gravity. Found in most of the self-pollinated tree crops. In this case pollen falls because of gravity on to receptive stigma of other flowers. This

mode is highly unreliable and also insignificant. The inflorescence or flowers will be in pendent or hanging down. The pollen grains are heavy in weight, usually in desepared tetrad form.

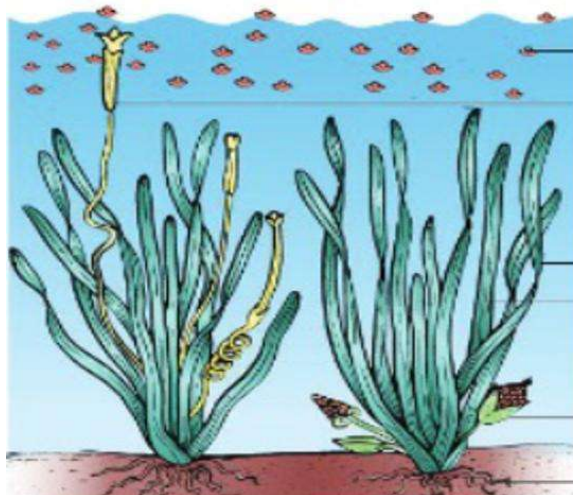


Fig. 1. Geophilic adaptation in tree species

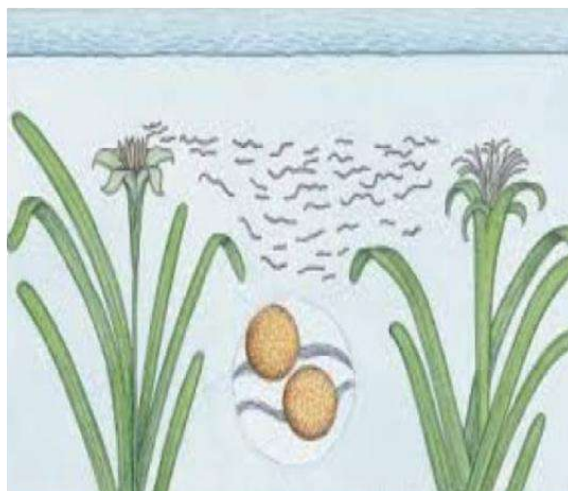
2. Hydrophily: Pollination is effected through water. Found only in some water plants, where the inflorescence floats or submerged. Flowers are smaller, inconspicuous, light in weight, colorless, and covered by waxy substances. Calyx and corolla are smaller than essential floral parts *i.e.* androecium and gynoecium. The dehiscence of anther takes place so violently that the pollen grains are scattered to a considerable distance. Pollen grains are small, lighter in weight, and coated with wax so that they can float on water and be carried by water current. Stigmas are long, sticky, and provided with bristles so they can catch pollen easily. In aquatic conditions, a close correlation between the position of flowers and specific gravity of pollen is necessary. Accordingly, hydrophily is classified into two types *viz.*,

a. Epihydrophily: The flowers get pollinated in floating water. The flowers are usually small and inconspicuous. In hyphydrophily, the stamens get separated from the flower and float on the surface of water. The anthers show presence of aerenchyma that helps it to float on the surface of water. The specific gravity of long pollen grains is same as that of water and hence get freely distributed throughout the water. The female flowers are attached to thin, spirally coiled by slender stalk that raise to the water surface. The floating male flowers get lodged in the cup shaped depression formed around female flowers bringing anther in contact with the stigma. The pollen gets trapped by the sticky surface of the style. *Eg.* Vallisneria.

b. Hypohydrophily: The flowers get pollinated when in submerged water. If female flowers are borne on submerged part, the pollen grains should possess a specific gravity slightly greater than water. So they sink down and get caught by stigma of female flower on the adaxial surface. The pollen reaches the large stigma of female flowers and pollination occurs in submerged water. The pollen grains are long, ribbon like and without exine. *Eg.* *Zostera* (Sea grass).



Epiphydrophily in Vallisneria (Ribbon grass)



Hypohydrophily in Zostera (Sea grass)

Fig. 2. Two types of Hydrophily in aquatic plants

3. Anemophily: Pollination is effected by wind. This is found in many plants like grasses. The plant will have reduced leaf surface area, exposed flower and reduced perianth. Anemophilous flowers are usually small and inconspicuous, and do not possess a scent or produce nectar. The stamens are long, pollen grains are smooth, dry, light weight with explosive anther dehiscence. The long style exposes the stigma outside the flower. The stigmas are branched, feathery bristly, or sticky so that they can catch floating pollens easily. Wild pollinated crops have usually abundant pollen production and wastage is huge in anemophily. The direction of wind also plays a major role in anemophily. Eg. Rice, Maize, Sugarcane, Brinjal, Coconut, Bamboo, Dates, Spinach etc.,



Anthesis in Maize Tassel



Anthesis in Sugarcane arrow



Anthesis in Bamboo inflorescence



Versatile anther



Smooth surfaced pollen grain for wind pollination

Fig. 3. Adaptations for wind pollination

4. Ombrophily: Pollination effected by rain splashes is known as ombrophily. In regions with frequent rain, some plants use rain-splash for pollination. This method helps in self-pollination when pollinators are scarce, providing a reproductive assurance strategy under adverse conditions. For example in orchid *Acamepe rigida*, the inflorescence has vertically oriented bow shaped spirally arranged flowers with fleshy sepals and petals. On the top of the stigma is the pollinarium containing two pollinia, a stipe on the midline, a viscidium and and rostellum on either side of stipe, followed by a stigmatic cavity to receive the pollen from the pollinia. Thus the orchid flower is architextured for self pollination when there is a moderate rain or drizzle that burst open the pollinia and release the pollen grains to run along the stipe guarded by viscidium and guided by rostellum to reach the stylar cavity located below.

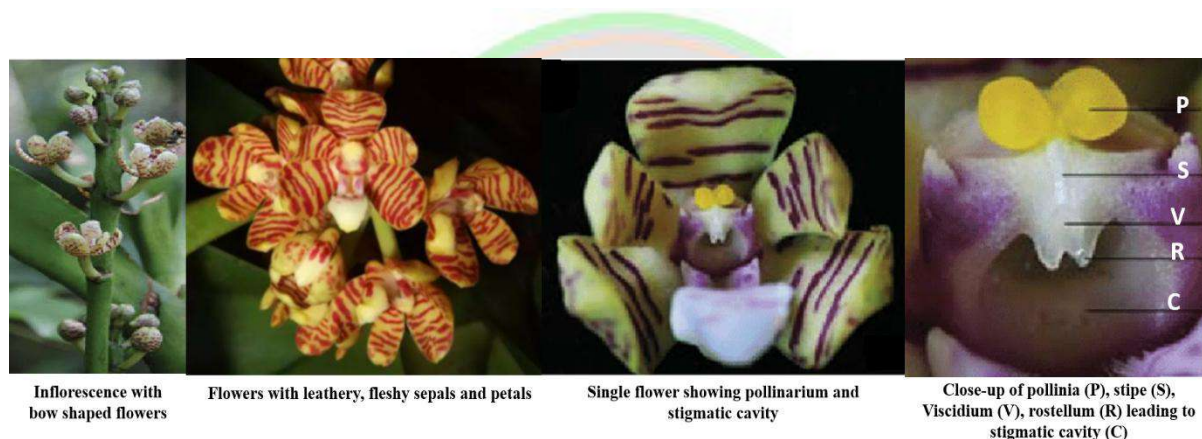


Fig. 4. Adaptations of *Acampe rigida* for rain pollination

II. Biophily (Biotic pollination): Involving living organisms as pollinating agents. This group is further classified into the following types viz.,

1. Entomophily: Pollination through insects is known as entomophily. Insects and flower show an amazing mutual adaptation that stimulate the insects to visit flowers on regular basis and stay on them long enough. The flowers are usually showy, bright coloured with strong odour and sticky pollen. Flowers have sufficient mechanical strength to prevent damage by the pollinator. The entomophilous flowers are larger in shape, bright colored, and showy so that they can attract insects. In insect pollinated flowers, the position of anther and stigma is such that when an insect takes food from the flower, it becomes dusted with pollen grains. It then transfers these pollen grains to the stigma of another flower during subsequent visit. If single flowers are smaller in shape, then they remain in a group to form inflorescence. The flowers which bloom at night emit a sweet scent to attract insects. Most of the entomophilous flowers have special landing platforms

for insects. The nectar glands situated at the base of the flowers secrete nectar which is one of the characteristic features of entomophilous flowers. Pollen grains are larger with rough, spiny, and sticky surfaces so that they can easily stick to the body of the insect. The stigmatic surface is rough and sticky to attach pollen grains firmly. Entomophily is further classified into 10 types viz.,

a. Melittophily or hymenopterophily: Pollination by bees. The flowers are of round heads with even outline, smaller in size with short tubes. Nectar guides strongly reflect UV lights. Nectar hidden atleast 4-10 mm within the flower or at times in a narrow tube. Flowers have resting platform and usually of blue to yellow, pink or white in colours. Bees perceive flowers which reflect yellow-green, blue-violet, and ultraviolet (UV) light. The petals in most of these flowers show the presence of colored lines or dark marks (dots, crosses, checks) which guide bees to the nectaries.

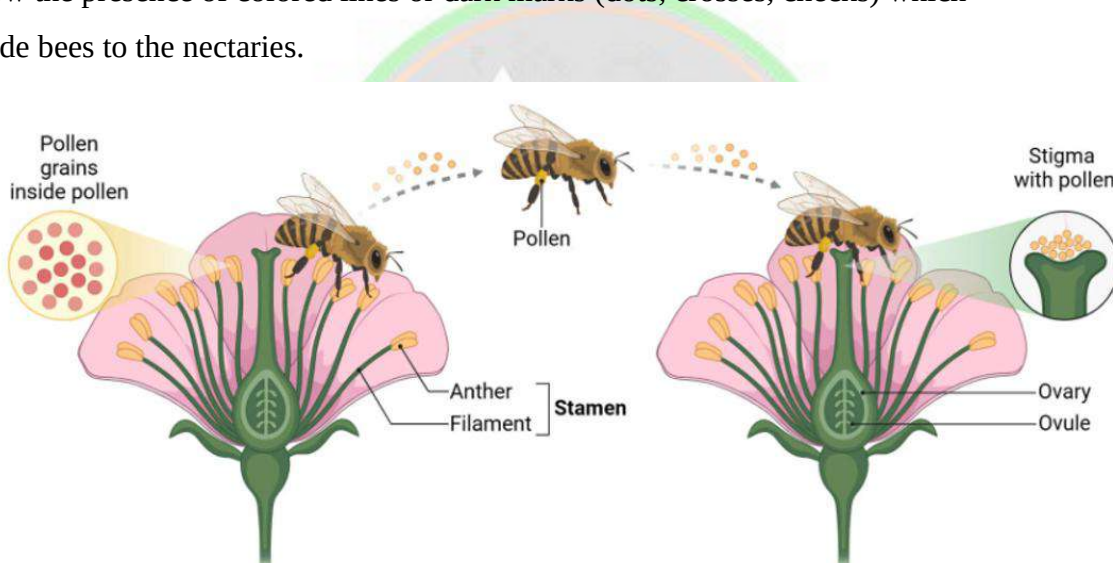


Fig. 5. Adaptations for bee pollination

The floral architecture ensures that insect transfers the pollen to the stigma. In garden *Nasturtium* nectar is held in a long narrow tube or spur. The bee directs its proboscis into the tube and rubs it against the stigma on the way thereby releasing the pollen. When bee/insect visits the flower for nectar its head pushes the sterile plate as a result of which the upper fertile lobe of the corolla lobe hits the insect on its back. Thus, pollen gets dusted on the back of the insects. When the bee visits another flower, the forked stigmas pick up the pollen from the back of the insect. More than 60 per cent of plants in the world are pollinated by honeybees. Eg. *Capsicum annum*, *Abelmoschus esculentus*, *Anacardium occidentale*, *Cucurbita maxima*, *Desmanthus virgatus*,

Elaeis guinensis, *Glycine max*, *Ipomoea batatas*, *Leucaena leucacephala*, *Mangifera indica*, *Medicago sativa*, *Nicotiana tabacum*, Sunflower, Chillies. Pumpkin, Alfalfa, Snapdragon, Lavender etc.,

b. Buzz pollination or Sonication: It is a technique used by some bees, such as [solitary bees](#) and [bumblebees](#), to release [pollen](#) which is more or less firmly held by the [anthers](#). The poricidal anthers of buzz-pollinated plant species are typically tubular, with an opening at only one end, and the pollen inside is smooth-grained and firmly attached. In order to release the pollen, solitary bees are able to grab onto the flower and move their flight muscles rapidly, causing the flower and anthers to vibrate, dislodging pollen. The flower morphology of buzz pollinated plants is different from that of other flora that do not use this type of pollination. The anthers are completely sealed except for a **small pore** at the top or have very small slits that open along the sides. The pores and slits are small enough that insects cannot easily enter the anther, but large enough pollen can exit. These poricidal anthers are only able to release pollen when vibrated at a specific [frequency](#). Pollination involving vibrations is called buzz pollination. Honeybees cannot perform buzz pollination. About 9% of the flowers of the world are primarily pollinated using buzz pollination. Eg. *Primula*, *Dodecatheon*, *Heliamphora*, *Solanum melongena*, *Lycopersicum lycopersicon*, Blue berries, Cranberries, *Senna auriculata*, etc.,

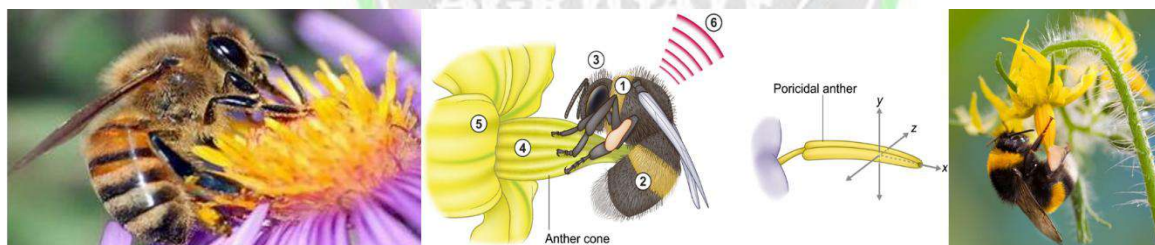


Fig. 6. Buzz pollination or Sonication by Bumble bee in *Solanum* like flower with poricidal anthers. The vibration by the thoracic muscles of bumble bee vibrates the poricidal anthers in X, Y and Z axes that make release of anthers through the pores of anthers.

c. Cantharophily: Pollination by beetles. Beetle-pollinated flowers are usually large, greenish or off-white in color and heavily scented and have landing platform. Scents may be spicy, fruity, or similar to decaying organic material. Most beetle-pollinated flowers are flattened or dish shaped, with pollen easily accessible, although they may include traps to keep the beetle longer. The plant's ovaries are usually well protected from the biting mouthparts of their pollinators. The flowers emit a strong fragrance similar to fermenting fruit or foul smell. Some of these flowers also produce heat internally which helps in the dispersal of odour. Eg. *Anacamphis morio* (an orchid), *Dioscorea alata*, *Bactris gasipaes*, and *Rudbeckia* spp.



Fig. 7. Canthrophily or pollination by beetles in plants.

d. Psychophily: Pollination by butterflies. Butterflies generally prefer red- or purple-coloured flowers with long narrow tube having undissected petal edges, with more nectar and agreeable odour. Butterfly lands on the flower and uses its palpi and antennae as sensory probes. The flowers have long nectar filled tubes. The nectaries are usually concealed in the flower; hence the mouthparts of butterflies have become suitably modified to reach the nectary. The butterflies visit the attractive flowers and long coiled tube- like tongue of butterfly is adapted to suck nectar. It punctures the nectary to suck the nectar. In the process, the pollen is dusted on the tongue and head of butterfly. Eg. Cashew, *Cinchona*, *Grewia asiatica*, *Anacardium occidentale*, *Cinchona calisaya*, *Cephaelis ipecacuanha*, etc.,



Fig. 8. Psychophily or pollination by butterflies in plants.

e. Phalaenophily: Pollination by moths is known as phalaenophily. The flower have nocturnal blooming, strong fragrances, and pale colors, which enhance visibility in low light conditions, making it easier for moths to locate these flowers at night. The flowers are either horizontal or pendent position with white or faint colours or with drab red colours. The nectar is deeply hidden in a long narrow tube. The flowers are primarily adapted to attract and facilitate the mating habits of moths. Eg. Papaya, Snake gourd, *Cananga odorata*, *Carica papaya*, *Yucca elephantipes*, *Trichosanthes cucumerina*, etc.,



Fig. 9. Phalaenophily or pollination by moths in plants.

f. Myophily: Pollination is carried out by flies is referred as Sapromyiophily. The flowers visited by flies are generally brown, white or yellow in colour and possess foul odours or fetid odour that is like the smell of rotting flesh or decomposing organic matter. Unlike bees, which actively collect pollen for their offspring, flies are generally unintentional pollinators. As they move from flower to flower in search of nourishment, they inadvertently transfer pollen from one bloom to another. The flowers are light or dull coloured with a shallow receptacle without much depth. *Eg. Colacasia antiquorum, Coffea arabica, Cinnamomum aromaticum, etc.,*



Fig. 10. Myophily or pollination by flies in plants

g. Sapromyophily: Pollination by Carrion flies is known as sapromyophily. Carrion flies pollinate flowers that emit foul smells, such as the Dead Horse Arum Lily. These flowers mimic the scent of rotting flesh to attract these flies. The plant provides them with no reward and they leave quickly unless it has traps to slow them down. Such plants are far less common than myophilous ones.



Fig. 11. Sapromyophily or pollination by Carrion flies in plants.

h. Symphytophily: Pollination by saw flies is known as symphytophily. The flowers are dull coloured with a shallow receptacle. *Eg.* Carrot, Lucern, Rose *etc.*,



Fig. 12. Symphytophily or pollination by sawfly in plants

i. Sphecophily: Pollination by Wasps is known as Sphecophily. They prefer dull coloured flowers with receptacles of moderate depth. The smell and colour of the female wasp matches with that of orchid flowers. The male wasp mistakes the flower as it is a female partner and carries out pseudocopulation. In the process the transfer of pollen takes place. In figs the pollination is done by wasps.



Fig. 13. Sphecophily or pollination by Wasp in Figs.

The inflorescence in figs is hypanthodium which consist of hollow flask shaped and succulent receptacle enclosing a cavity which opens outside by a pore. The inner surface of receptacle

bears sessile and unisexual flowers. The male flowers are present at upper end while the female flowers are present at the base. The female flowers are either long-styled or short-styled called gall flower. The wasp lays its eggs in the ovaries of gall flowers. The female wasp enters the hypanthodium through apical pore reaches the ovaries of gall flowers, lays its eggs and while moving out gets dusted with the pollen from the anthers of male flowers. The wasp having pollen when it goes to another hypanthodium enters the long-styled flowers depositing the pollen on the surface of stigma causing pollination. Eg. *Ophrys speculum*, *Ziziphus jujoba*, *Sesamum indicum*, *Ficus carica*, etc.,

j. Myrmecophily: Pollination by ants is known as myrmecophily. The flowers are hairy and have lip like corolla to trap the ants. The flowers mostly have no nectar, but pollen is in hidden state. Ants visit inconspicuous, low-growing flowers positioned close to the stem. Sometimes flowers supply nectaries outside the flowers to attract ants that keep other insects from stealing the nectar (by entering the flower from the side) forcing them to enter the flower in a way that is more conducive to pollination. Eg. Small's stonecrop (*Diamorpha smallii*), alpine nailwort (*Paronychia pulvinata*), and Cascade knotweed (*Polygonum cascadenense*),



Fig. 14. Myrmecophily or pollination by ants in plants.

k. Thysanophily: Pollination by thrips is known as Thysanophily. The flowers are colourful with hairs and with prominent margin. By virtue of their pollen feeding habit, thrips visit the flowers during anthesis and carry appreciable number of pollen grains and incidentally transfer them on to the stigma during their inter and intra movement between the flowers/florets/inflorescence. Pollen grains attached to the body setae, wings and legs of thrips are dispersed on the



Fig. 15. Thysanophily or pollination by thrips in plants

stigma by way of their active movement, rubbing the abdomen on the stigmatic surface, cleansing of their body parts with their hind legs and also by their wing combing mechanism.

Thrips movement within the flower involves frequent spreading and shaking of wings, body grooming and trivial flight take-off from the florets etc. In many flowers, stigma is very prominent and that is being used by thrips for landing and take-off. During this process, thrips places the pollen directly on the stigma. The impressive petal colour and corolla tube of a small flower form an ideal site to attract thrips for oviposition, enabling the emerging larvae to become dusted with pollen in their upward and downward movement eventually leading to pollination. Eg. *Shorea robusta*, *Phaseolus vulgaris*, *Chenopodium album*, *Beta vulgaris*, etc.,

2. Zoophily: Pollination by vertebrates is known as zoophily. They feed on the nectar of several plant species. These pollinators mainly include birds, bats, marsupials, primates, and rodents. In animal pollinating species, nectar and pollen need to be present in surplus to facilitate pollination. Animals pollinate flower species with characteristic morphology, colour, and odour. Red flowers having little odour are generally pollinated through animals. Animal pollinators get benefitted by getting nectar and pollen. Zoophily is has two major types viz.,

- a. **Chiropterophily:** Pollination by bat is known as chiropterophily. They prefer flowers that open at dusk or at night. These are large sized flowers with prominent mouth and long swinging pedicels. They usually prefer brush type inflorescence and the flowers are arranged in a pagoda structure.



Fig. 16. Chiropterophily or pollination by bats in plants.

The flowers are generally white, cream or purple in colour with hidden and diluted nectar. The flowers have strong musty odour. Eg. *Syzygium jambolans*, *Musa paradisiaca*, *Agave americana*, *Bauhinia megalandra*, *Kigelia pinnata* (Sausage tree), *Anthocephalus* (Kadam tree), *Adansonia* (Boabab tree), *Syzygium jambos*, *Pentadesma butyraceae*, *Persea armeniacana*, *Agave spp.* *Musa spp.* etc.,

b. Ornithophily: Pollination by birds is known as ornithophily. Birds like Sunbirds, Lories, Humming birds, Flowerpeckers, Crow, Bulbuls, Parrots and Mayna are important bird pollinators. Bird pollinated flowers are deep tubular or spurred, leather textured petals with ridges. Most

birds have a good colour sense and excellent vision but have poor sense of smell. Flowers pollinated by specialist nectarivores tend to be large, red or orange tubes with a lot of dilute nectar, secreted during the day. Since birds do not have a strong response to scent, they tend to be odorless. Flowers pollinated by generalist birds are often shorter and wider. Hummingbirds are often associated with pendulous flowers, whereas passerines (perching birds) need a landing platform so flowers and surrounding structures are often more robust. Also, many plants have anthers placed in the flower

so that pollen rubs against the birds head/back as the bird reaches in for nectar. These flowers have sugar rich nectar, hidden deep inside the flower. They open in the morning hours. Eg. Papaya, Custard apple, *Grewia asiatica*, *Musa textilis*, *Ananas cosmosus*, *Bombax ceiba*, *Butea monosperma*, *Fuchsia*, *Hibiscus*, *Erythrina indica*, *Bignonia*, etc.,



Fig. 17. Ornithophily or pollination by birds in plants.

3. Malacophily: Pollination by snails and slugs is known as malacophily. This mode of pollination occurs mostly in aquatic plants. Usually, snail pollination occurs on stormy rainy days, wherein bees are not available. Eg. Aroids, *Arisaema* (Cobra plant), Arum, Lilies, *Aspidistra lurida*, *Chrysanthemum leucanthemum*, *Volvulopsis nummularium*, etc.,



Fig. 18. Malacophily or pollination by snails in plants.

Mechanisms and adaptations of plants to attract pollinators

1. Floral structures: Usually, most of the flowers are developed according to different pollinators. For example, entomophilous flowers are usually brightly colored, and showy, with nectar-producing glands and fragrances. Ornithophilous flowers are usually larger, and tubular, to attract birds like hummingbirds. However, flowers having abiotic pollinators are usually unattractive. The hydrophilous flowers usually have a coating of cuticles around pollens to protect them from water.



Fig. 19. Flower structural adaptations that attracts pollinators. A. Adaptation for bat pollination. B & C Adaptation for Bird pollination

2. Food reward: Nectar acts as a food reward for pollinators and fragrances help to attract insects and animals.

3. Energy: Some thermogenic plants can maintain relatively higher temperatures than the environment to maintain the microclimate of the flower. For example, some plants have larger bracts to minimize heat loss. This floral heat provides energy to the pollinators and in return, the flower gets pollinated. Some thermoregulatory plants include- *Philodendron selloum*, *Nelumbo nucifera* etc.

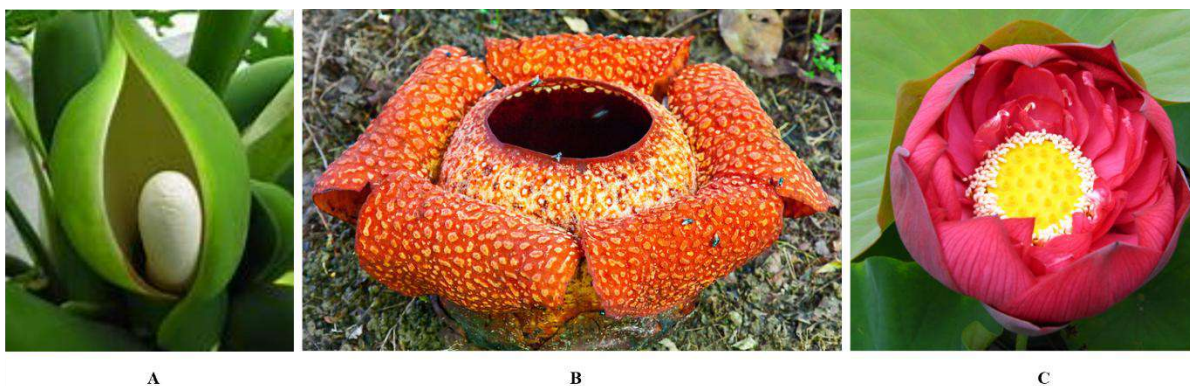


Fig. 20. Thermogenic plants that maintains relatively higher microclimate temperatures inside the flowers to attract pollinators. A. *Philodendron selloum*, B. *Rajjiesia sp.* and C. *Nelumbo nucifera*

4. Mimicry: In this type, the flowers do not provide food for pollinators, but they mimic the shape, odor, and other insects to attract the pollinators. For example, *Acianthera adamantiensis* mimics the odor of dog feces to attract flies. In an orchid species *Ophrys*, the flower resembles a bee to attract male bees for copulation (pseudocopulation) which thus leads to pollination.



Fig. 22. The flower of *Arum palestinum* (Solomon's Lily) secretes a scent to attract *Drosophila* spp. (Fruit fly) for effecting pollination

5. Floral traps: In species like *Nymphaea*, the flowers containing stigmatic fluid open to attract insects, and the visiting insects eventually fall into the cup and get drowned which leads to washing off all the pollen on the visiting insects to pollinate the plants.



Fig. 21 A bee mimic Orchid flower that resemble female bee to attract male bee for pollination.

6. Co-evolution: Both plants and their specific pollinators have co-evolved for specialized relationships. For example, orchids have developed certain structures to attract insects like bees.

PHARMACEUTICAL POTENTIAL OF *CHROMOLAENA ODORATA*: A MINI REVIEW

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Abstract

Chromolaena odorata, commonly known as Siam weed, has traditionally been viewed as an invasive species, yet emerging research highlights its substantial pharmacological potential. Rich in bioactive compounds such as flavonoids, terpenoids, alkaloids, and phenolic acids, the plant exhibits diverse therapeutic properties including antimicrobial, antioxidant, anti-inflammatory, wound healing, and anticancer activities. These effects are mediated through mechanisms such as free radical scavenging, inhibition of pro-inflammatory mediators, disruption of microbial cell integrity, and induction of apoptosis in cancer cells. Experimental studies validate its effectiveness against a range of bacterial, fungal, and viral pathogens, while also demonstrating its ability to modulate oxidative stress and enhance tissue regeneration. Given its wide range of bioactivities and traditional uses, *C. odorata* stands as a useful plant for the development of plant-based pharmaceutical agents. This mini-review synthesizes the current scientific understanding of *C. odorata*'s pharmacological applications and underscores its potential as a valuable resource in modern medicine.

Introduction

Siam weed (*Chromolaena odorata*) is often regarded as an invasive species due to its aggressive growth and ability to dominate ecosystems. However, beneath its notorious reputation lies a plant with immense potential for advanced applications across various sectors. Scientific studies have uncovered a wide range of bioactive compounds in *C. odorata*, making it a valuable resource for innovative solutions in medicine, agriculture, environmental conservation, and industry.

These advanced uses not only showcase the plant's versatility but also highlight how thoughtful research and management can transform a challenge into an opportunity.

Siam weed has gained significant attention in the pharmaceutical field due to its rich phytochemical profile. The secondary metabolite compounds have demonstrated potential in addressing some of the most pressing healthcare challenges, from combating infections to preventing chronic diseases. The antioxidant properties of *C. odorata*, primarily attributed to flavonoids and phenolic acids, are critical in neutralizing free radicals and reducing oxidative stress (Mohammad *et al.*, 2022). Oxidative stress is a major contributor to chronic diseases such as cardiovascular conditions, neurodegenerative disorders, and diabetes. Scavenging free radicals and protecting cellular components, *C. odorata* supports the prevention of these conditions. Its anti-inflammatory mechanisms involve the inhibition of pro-inflammatory cytokines and enzymes such as cyclooxygenase (COX), makes it effective in managing conditions like arthritis and inflammatory bowel disease. The antimicrobial properties of *C. odorata* are linked to its alkaloids, terpenoids, and tannins, which interfere with microbial growth and survival (Sabri and Yusuf, 2021).

These compounds disrupt bacterial cell walls, inhibit enzymatic activity, and impair the replication of pathogens. This makes *C. odorata* a potential source for developing natural antibiotics, especially in the fight against antibiotic-resistant bacteria. Research has shown that certain compounds in *C. odorata*, such as flavonoids and terpenoids, exhibit cytotoxic effects on cancer cells (Yusuf *et al.*, 2023). These compounds induce apoptosis (programmed cell death) in cancer cells by activating pathways such as the mitochondrial apoptosis pathway and caspase cascades. It also inhibits angiogenesis, the process by which tumors develop new blood vessels, effectively starving cancer cells of nutrients. This dual action positions *C. odorata* as a potential source for novel anticancer agents.

Antimicrobial activity

Chromolaena odorata has demonstrated significant antimicrobial activity against a wide range of bacterial, fungal, and viral pathogens, positioning it as a promising candidate for developing natural therapeutic agents. The plant is rich in phytochemical composition, particularly its flavonoids, phenolics, alkaloids, and essential oils that underpins its antimicrobial properties. Against bacterial pathogens, *C. odorata* exhibits strong inhibitory effects on both Gram-positive and Gram-negative species, including *Escherichia coli*, *Staphylococcus aureus*,

and *Pseudomonas aeruginosa* (Omokhua-Uyi *et al.*, 2020). These effects are largely attributed to phenolic acids and flavonoids, which disrupt bacterial cell membranes, inhibit enzyme activity, and induce oxidative stress. Similarly, its antifungal activity is evident against species like *Candida albicans* and *Aspergillus niger*, with mechanisms involving the disruption of fungal cell wall integrity and inhibition of ergosterol biosynthesis, likely mediated by terpenoids and tannins (Mathew *et al.*, 2022). In terms of antiviral potential, *C. odorata* shows positive effect against viruses like herpes simplex virus (HSV) and influenza, possibly by interfering with viral replication and entry mechanisms, though further studies are required to elucidate specific pathways. These antimicrobial activities not only highlight the plant's therapeutic potential but also underscore the need for deeper investigations into its mechanisms of action to facilitate the development of effective plant-based antimicrobial agents.

Antioxidant properties

The plant's phytochemicals act as efficient free radical scavengers by donating hydrogen atoms or electrons, thereby stabilizing reactive oxygen species (ROS) and reactive nitrogen species (RNS). Studies have shown that extracts from *C. odorata* demonstrate significant inhibition of lipid peroxidation, protection against DNA damage, and preservation of cellular integrity (Usunobun *et al.*, 2024). In health applications, the antioxidant activity of *C. odorata* has potential therapeutic implications in managing oxidative stress-related diseases, such as cardiovascular disorders, neurodegenerative conditions, and cancer. Its ability to mitigate oxidative damage supports its use in traditional medicine for wound healing and inflammation management. In the food industry, *C. odorata* extracts could serve as natural preservatives to prolong shelf life by preventing the oxidation of fats and oils in food products. Its incorporation into functional foods and nutraceuticals further highlights its promise in promoting health and reducing disease risk. The broad-spectrum antioxidant capabilities of *C. odorata* underscore its significance as a sustainable and versatile resource for diverse applications in health and industry.

Wood healing and anti-inflammatory effects

Chromolaena odorata has long been recognized in traditional medicine for its remarkable wound healing and anti-inflammatory properties, which are supported by growing experimental evidence. In many cultures, the leaves of the plant are crushed into a paste and applied directly to wounds to promote rapid healing, reduce swelling, and prevent infection. Experimental studies

have confirmed that *C. odorata* enhances wound contraction, increases tensile strength of healed tissue, and accelerates epithelialization. Its flavonoids and phenolic acids are known to promote angiogenesis and collagen synthesis, both of which are responsible for tissue regeneration. Tannins exert an astringent effect, which helps in clot formation and reduces wound exudate (Fadlilah *et al.*, 2021). The antimicrobial properties of *C. odorata* further prevent wound infections, ensuring a sterile healing environment. The plant's anti-inflammatory activity is equally notable, with studies demonstrating its ability to inhibit pro-inflammatory mediators such as prostaglandins, cytokines, and nitric oxide. This activity is mediated by the suppression of cyclooxygenase (COX) and lipoxygenase (LOX) pathways, as well as the stabilization of cell membranes, reducing inflammation and swelling.

Anticancer Potential

Chromolaena odorata has emerged as a promising candidate in cancer research due to its demonstrated cytotoxic effects against various cancer cell lines. The plant's bioactive compounds, particularly flavonoids, alkaloids, terpenoids, and phenolic acids, contribute significantly to its anticancer activity by targeting multiple pathways involved in tumor growth and progression. Studies have shown that extracts of *C. odorata* exhibit selective cytotoxicity, effectively inducing apoptosis and inhibiting proliferation in cancer cells while sparing normal, healthy cells. Experimental investigations have reported cytotoxic effects of *C. odorata* on cell lines such as human breast cancer (MCF-7), lung cancer (A549), and cervical cancer (HeLa), among others (Kulaphisit *et al.*, 2023). The mechanisms underlying these effects include the induction of mitochondrial-mediated apoptosis, disruption of the cell cycle, and inhibition of angiogenesis. For instance, flavonoids like quercetin and kaempferol have been shown to trigger oxidative stress in cancer cells by increasing intracellular reactive oxygen species (ROS) levels, leading to mitochondrial dysfunction and cell death. Terpenoids, on the other hand, are believed to interfere with key signaling pathways such as the PI3K/AKT and MAPK pathways, which are critical for cell survival and proliferation.

Phenolic acids in *C. odorata* also exhibit strong antioxidant activity, which helps to modulate oxidative damage and reduce chronic inflammation, a known precursor to cancer development. Alkaloids have been identified as potent DNA intercalators and topoisomerase inhibitors, disrupting the replication machinery in cancer cells. The plant's cytotoxic activity, coupled with its ability to inhibit metastatic potential, highlights its therapeutic relevance in

developing plant-based anticancer treatments. Although promising, further research is required to fully elucidate the specific molecular mechanisms and to evaluate the efficacy and safety of *C. odorata* in preclinical and clinical settings. These findings underscore its potential as a source of novel anticancer compounds, paving the way for more targeted and sustainable cancer therapies.

Table 1. Experimental evidence supporting the pharmaceutical applications of *Chromolaena odorata*

Activity	Target pathogen/Disease	Experimental model/ study	Findings
Antibacterial	<i>Escherichia coli</i> , <i>Staphylococcus aureus</i> , <i>Pseudomonas aeruginosa</i>	Omokhua-Uyi <i>et al.</i> (2020)	Strong inhibition through disruption of bacterial membranes and enzymatic activity
Antifungal	<i>Candida albicans</i> , <i>Aspergillus niger</i>	Mathew <i>et al.</i> (2022)	Disruption and fungal cell wall integrity and ergosterol biosynthesis
Antioxidant	Oxidative stress in methotrexate induced nephropathy	Usunobun <i>et al.</i> (2024)	Reduced oxidative markers; protection of kidney tissues
Wound healing	Acute cutaneous wounds	Fadlilah <i>et al.</i> (2021)	Accelerated healing, clot formation and reduced bleeding time
Anti-inflammatory	Inflammatory swelling and pain	Cahyo <i>et al.</i> (2021)	Inhibition of COX, LOX and inflammatory cytokines
Anticancer	Breast (MCF-7), Lung (A549), Cervical (HeLa) cancer cell lines	Yusuf <i>et al.</i> (2023); Kulaphisit <i>et al.</i> (2023)	Induced apoptosis, inhibited proliferation and angiogenesis in cancer cells

Conclusion

Chromolaena odorata demonstrates impressive pharmacological potential through its broad spectrum of bioactive compounds and mechanisms of action. Scientific evidence supports its antimicrobial efficacy against multiple pathogens, its antioxidant capacity to mitigate

oxidative stress, and its role in promoting wound healing and reducing inflammation. Its selective cytotoxicity against cancer cells positions it as a potential source of novel anticancer agents. These findings not only validate its traditional medicinal uses but also encourage further investigation into its safety, efficacy, and clinical relevance. With continued research and proper formulation, *C. odorata* could transition from a traditionally used herb to a scientifically backed therapeutic resource, contributing to the advancement of plant-based medicine and sustainable healthcare solutions.

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THE SECRET OF THE SWIRL

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Abstract

The captivating swirling patterns observed in many seashells arise from a combination of biological growth processes and underlying mathematical principles. This article explores the primary mechanism responsible for this characteristic shape: the logarithmic spiral. We also discuss the biological aspects that let various seashell morphologies realise this exquisite geometric shape, including the mantle's function in secretion and the ongoing deposition of shell material at the expanding edge. These natural structures' lovely and dependable whirling patterns are the result of a synthesis between mathematical requirements and biological execution.

Introduction

Seashells exhibit a remarkable variety of complex colouring patterns (Hedegaard et.al., 2006). Seashells are classified within the phylum Mollusca, which is further divided into classes like Gastropoda (snails), Bivalvia (clams), and Cephalopoda (nautilus). Gastropods, with their single, often spiraled shells, are particularly significant due to their vast diversity and ecological roles.

The swirling patterns of these gastropods have captivated human fascination for centuries, representing a perfect blend of natural artistry and mathematical precision. They are detailed documentations of the molluscs' lives. From the delicate spirals of the nautilus to the bold whorls of the conch, each shell boasts a unique design, a testament to the diversity of marine life. The multilayered exoskeleton of a seashell protects the bodies and life of molluscs (Source: Miette Broussard).

Seashells have an amazing variety of colours and textures in addition to their shape (source: Megan Kalomiris). Their colours are as varied as the ocean itself, ranging from vivid oranges, blues, and browns to iridescent whites and creams. No two shells are alike. The stationary patterns seem to be fixed, and in fact, they are made up of calcified material (Chateigner et.al., 2000). The beauty beneath this beautiful mechanism is remarkably dynamic. This spiraled structure offers a compact yet robust defense, allowing the gastropod to retreat fully within its shell. Additionally, the shell's form can reflect adaptations to specific environments, influencing how the animal interacts with its surroundings, making the gastropod shell a fascinating example of evolutionary adaptation.

Composition

Molluscs are masters at the fabrication of shells. Because they are made of the widest range of microstructures among invertebrates. Highly organised aggregates of aragonite or calcite crystals with a variety of morphologies and three-dimensional configurations are known to be molluscan microstructures (Meinhardt, 1995). The 'Cambrian explosion' was accompanied by the diversification of biomineralization pathways, emphasizing the significance of this feature (Marshall, 2003).

Despite its small volumetric representation, the organic fraction is extremely complex, with hundreds of proteins, polysaccharides, and lipids, which can differ according to molluscan group. Traditionally, proteins are responsible for all aspects of the creation of microstructural aggregates. Direct evidence exists indicating that the mineral phase is influenced by soluble proteins, while nucleation and crystal shape are supported by indirect evidence. The formation of intergranular organic matrices characteristic of certain microstructures, such as nacre and columnar prismatic structures, cannot be accounted for by a protein-based explanation. (Checa, 2018).

Several other mechanisms play a crucial role in the organisation of molluscan microstructures alongside protein activity. The equilibrium between physical and biological determinants differs across microstructures, with certain structures relying solely on either physical or biological processes, while others exhibit a combination of both (Ubukata, 1994). Some their shells (Nudelman et al., 2007; Baronnet et al., 2008). A tiny portion of the original ACC can be permanently stabilised within the biominerals, according to current knowledge (Macías-Sánchez et al., 2025).

The Mechanism

Shell, a byproduct of biomineralisation, keeps their internal environment steady and shields them from predators (Sonak, 2017). Shell formation mechanism provides fundamental information on polymorphic morphological structures and special mechanical properties. The architectural and color features are patterned by the anterior edge of the mantle tissue, which supports the shell's lip and guides the orderly biomineralization of its many structural layers (Weiner et al., 2005). The color, shape, and geometric pattern of a seashell directly reflect the gene expression activity of the mantle during a mollusc's life and serve as a historical record of the integration of proteins into the shell matrix and onto its surface (Brusca and Brusca, 2003).

Orientated attachment, accumulation of amorphous calcium carbonate precursors, and classical nucleation theory are the three **primary hypotheses** of the shell formation mechanism (De-Yoreo et al., 2015; Feng et al., 2017 and Yao et al., 2017). Shell formation relies on several key proteins, including epidermal growth factor (EGF), fibronectin type III (FN3), whey acidic protein (WAP), and chitin-binding (CB), which provide valuable information about biomineralization processes (Clark et al., 2020; Liu et al., 2021 and Shimizu et al., 2022). Lustrin-A (Shen et al., 1997) gives the nacreous layer elastomeric, fracture-resistant qualities, and macromolecules extracted from calcitic or nacreous environments can influence the kind of CaCO_3 polymorph that is deposited in vitro (Thompson et al., 2000).

Shell development in molluscs is induced by the mantle, which is linked to shell growth and colouration (Song et al., 2022, and Parvizi et al., 2023). The mantle epithelium secretes organic macromolecules (proteins, glycoproteins, lipids, and polysaccharides) and CaCO_3 to form the mollusc shell, which is formed extracellularly (Marin and Luquet, 2004). The creation of a shell involves the movement of both organic materials and inorganic ions to the space between the mantle and the shell's inner surface, where they solidify into mineralized layers (Marin et al., 1996).

Shell matrix proteins (SMPs) play an essential role in most mollusc biomineralization processes. Proteins and polysaccharides are among the first organic materials to be carried to the extrapallial space, which is the slender area between the mantle and the existing shell. Inorganic ions, mostly calcium carbonate, are also supplied to this area concurrently. Following their interaction, these elements create an organic matrix framework that serves as the nucleation and growth site for calcium carbonate crystals. Different shell layers with unique microstructures and

compositions are produced as a result of this regulated deposition. The process is finely regulated, allowing gastropods to produce shells with diverse shapes, sizes, and intricate patterns, providing both protection and structural support.

The Pattern

The spiral shape is the most distinctive feature of a shell. As they get bigger, molluscs—the organisms that live inside shells—need more room. A spiral structure forms as the mollusc becomes bigger because the material of the shell only multiplies more quickly close to the aperture.

A whorl is a single, complete 360° revolution or turn in the spiral or whorled growth of a mollusc shell. The number of whorls depends on mathematical factors in the geometric growth. Each new whorl is larger than the old or the **previous one**, and the spiral formation gives strength and protection for the snail. The whorls can differ with respect to number, shape, and size depending on the species. The variance in a shell's external appearance is determined by its development rate, which can be mathematically explained, even using basic geometry. (Source: Miette Broussard/blog).

Logarithmic Spirals

One way to characterise their mathematical appearance is as a "generating curve" or "generating spiral." Only the breadth increases and the angles remain constant as a result of the expansion and spiral caused by the semi-circular opening's rotation and upward lift. (Source: Miette Broussard).



Neverita spp. (showing the pattern of dark bands) Turritella spp. showing narrow whorls

The displacement of an exponentially expanding curve along a constant, or logarithmic spiral, yields mathematical shells. The breadth between the innermost centre point and the outside rim

of the shell, as well as the upward distance from the starting point, both grow with each angle revolution (Kouchinsky, 2000).

Conclusion

The swirling patterns adorning mollusc shells represent a fascinating intersection of biological artistry and scientific complexity. These intricate designs, born from a confluence of genetic programming, chemical interactions, and environmental influences, contribute significantly to the organism's survival through camouflage, species recognition, and potentially, thermal regulation. The mathematical models employed to describe these patterns, from fractal geometry to reaction-diffusion equations, highlight the underlying order and precision of nature's design. Seashells were money before coin, jewellery before gems, art before canvas. The voice of a seashell has frequently summoned worshippers, scientists, and diviners together with messages.

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C4 RICE

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Abstract

As the world population races toward 10 billion, agricultural scientists are realizing that another “green revolution” is needed for crop yields to meet demands for food. In rice, yield potential is limited by the photosynthetic capacity of leaves that, as carbohydrate factories, are unable to fill the larger number of florets of modern rice plants. One potential solution is to introduce a higher-capacity photosynthetic mechanism—the C4 pathway—into rice. This is the goal of researchers in the international C4 Rice Consortium: to identify and engineer the genes necessary to install C4 photosynthesis in rice.

Introduction

Rice (*Oryza sativa*) is a staple food for over half of the global population, especially in Asia, Africa, and Latin America. As the world faces mounting challenges from population growth, climate change, and limited arable land, increasing the productivity of rice has become a critical goal for food security. One of the most ambitious strategies in this direction is the development of C4 rice—a genetically engineered rice variety that utilizes the C4 photosynthetic pathway, a more efficient mechanism for converting sunlight into energy. While rice is naturally a C3 plant, the incorporation of C4 traits could lead to significant increases in yield, nitrogen use efficiency, and drought tolerance. Rice is a staple food for more than half the world's population and a combination of population growth and land lost to urbanization means that by 2050, rice yields have to increase by over 50%. Unfortunately, pushing up rice production has become increasingly difficult. Between 1970 and 1990, rice yield per hectare grew at an average of 2.3% a year. Now-a-days the production has been decreased to 1.5%. The numbers suggest that

biologists need new approaches and one of the boldest being tried is the C4 Rice Project. The project, involving an international consortium of researchers, aims to boost yields by half by creating rice that uses highly efficient C4 photosynthesis.

During photosynthesis, plants capture carbon dioxide from the air and use it to build sugars. Unfortunately, the enzyme that first binds CO₂ – called RuBisCO - sometimes binds oxygen by mistake. When this happens, it triggers a series of reactions called photorespiration. Given equal amounts of CO₂ and O₂ this would not be much of a problem. RuBisCO is much more likely to bind CO₂. But RuBisCO isn't given an even choice-there's far more O₂ than CO₂ in the atmosphere. Things get worse as the temperature increases. When it's hot, RuBisCO is more likely to bind O₂ than CO₂. At temperatures above 30°C, this can mean photorespiration reduces the net rate of photosynthesis by **over 30%**. Photorespiration occurs in all plants using conventional photosynthesis - called C3 photosynthesis because the first products detected after RuBisCO fixes CO₂ are 3-carbon molecules. Some plants, however, escape the problem. Instead of using RuBisCO to capture atmospheric CO₂, these plants use an enzyme that doesn't bind oxygen. The enzyme fixes CO₂ in a reaction that transforms a 3-carbon molecule into a 4-carbon molecule - hence the name, C4 photosynthesis.

C4 plants haven't abandoned RuBisCO. C4 photosynthesis is effectively the normal, C3 version of photosynthesis, but with the addition of a CO₂ pump. The pump operates across two types of cell. First, mesophyll cells in the leaf capture CO₂ to produce 4-carbon molecules. These are then exported to neighbouring bundle sheath cells, which strip CO₂ from the 4-carbon molecules and feed it to RuBisCO. The process converts the 4-carbon molecules to 3-carbon molecules, which are recycled back to mesophyll cells to help capture more CO₂. The C4 mechanism can pump up the concentration of CO₂ around RuBisCO more than tenfold, making it highly unlikely that RuBisCO will bind O₂ rather than CO₂. The process is often compared to a turbo-charger, which increases an engine's power by pumping air into the combustion chamber. C4 also has other advantages. The boost to photosynthesis means C4 plants can use less RuBisCO than C3 plants, saving on the nitrogen needed to build the protein. In addition, C4 plants can survive on a lower overall CO₂ concentration in the leaf, allowing them to keep stomata partially closed and so save water. Researchers estimate that in semi-arid, warm regions, C4 allows plants to increase net photosynthesis by around 50%. Interestingly, a mechanism called CAM (Crassulacean Acid Metabolism) that is similar to C4 has evolved in desert plants.

CAM plants open their stomata at night and fix CO₂ into 4- carbon molecules. During the day, they close their stomata to save water, and release CO₂ from the 4-carbon molecules to allow photosynthesis.

The current focus is to discover if it is possible to change both rice biochemistry and the structure of rice leaves to a more C₄ type. Comparing the leaves of maize (C₄) and rice we can easily found out that the presence of a prominent bundle sheath surrounding the vascular bundles is the major peculiar difference that is found only in the leaf of the C₄ plant. This anatomical specialization of a C₄ leaf is called “Kranz anatomy”. Kranz, is a german word which means wreath in english, due to the ring like arrangement of bundle sheath cells. It separates the fixation of CO₂ into 4-carbon molecules in mesophyll cells from its use by RuBisCO in bundle sheath cells. Almost all C₄ plants have Kranz anatomy, suggesting it will have to be bred into rice. Alongside this, rice biochemistry will have to be rewired to create the CO₂ pump. One simple example is in the pattern of RuBisCO activity.

C₄ depends on RuBisCO being confined to bundle sheath cells—away from the low CO₂ concentrations in mesophyll cells. In present day rice, however, most of the plant’s RuBisCO exists in mesophyll cells. “These two traits—biochemistry and anatomy—are both critical for the functioning of an efficient C₄ leaf”. Years ago, to a low of around 200 ppm 20,000 years ago. As CO₂ concentrations fell, the problem of photorespiration increased and so did the advantage of C₄ photosynthesis. This has driven the evolution of C₄ species, which is now dominating several ecosystems, for example, many types of grassland. Hibberd says that “There is a massive biological resource out there for us to use to understand what it really takes to be C₄”. Researchers are applying modern molecular biology and data analysis to unpick the genetic changes through which C₄ plants evolved. So far, their research shows that although each case involves slightly different genetic changes, the end results are remarkably similar in both biochemistry and leaf structure. “The repeated evolution of this complex system implies that there are some relatively simple genetic switches that control it,” says Hibberd. Currently, researchers plan to genetically engineer rice with C₄ plants, such as maize. This means the project will have to satisfy national and international regulatory frameworks on the use of genetic engineering in crops. The research teams involved will also consult with both rice farmers and the public before launching C₄ varieties.

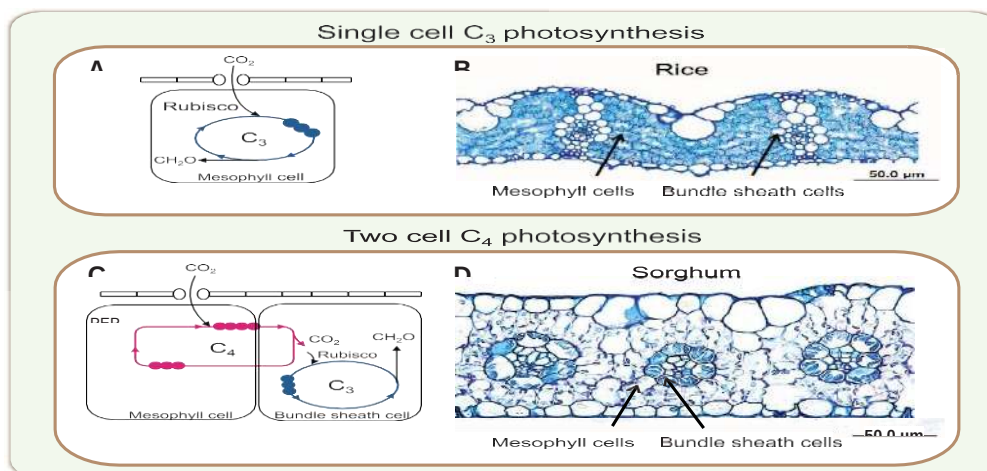


Fig. 1. (A). C₃ photosynthesis fixes atmospheric CO₂ into C₃ acids with Rubisco in single cells. (C). Two-cell C₄ photosynthesis requires spatial separation of fixation of atmospheric CO₂ into C₄ acids and the donation of CO₂ from these C₄ acids to Rubisco. Also shown the images of transverse sections of leaves of (B) Rice, a C₃ plant, and (D) Sorghum, a C₄ plant.

Lessons learned and Future challenges:

Although C₄ leaves have close veins and high rates of photosynthesis, C₄ photosynthesis is also naturally supported around widely spaced veins in maize husk tissue, albeit at lower rates. Thus, a prototype C₄ rice may be achievable with a subset of C₄ genes, but a “good” C₄ rice will require substantial fine tuning of biochemistry and anatomy. Particularly intriguing is the need for additional metabolite transport across membranes of organelles in C₄ photosynthesis. A functional C₄-concentrating mechanism in rice would allow for an approximately two-thirds reduction in Rubisco levels, relative to wild-type rice, but Rubisco would be sequestered in bundle sheath cells and ideally have a greater catalytic turnover rate. Antisense gene suppression of key photosynthetic enzymes has illuminated C₄ metabolism and engineering strategies, including the surprising find that phosphorylation of phosphoenolpyruvate (PEP) carboxylase by the regulatory enzyme PEP carboxylase phosphokinase is not needed for C₄ function. With the adoption of the C₄ model plant *S. viridis*—with its short life cycle, small stature, and genome size—along with advances in efficient transformation, we anticipate that much more will soon be learned. We expect to have a C₄ rice prototype within 3 years. However, we estimate that another 15 years of research are required for optimization of the phenotype and field testing for C₄ rice to become ready for cultivation in farmers’ fields. Norman Borlaug’s green revolution was based on just a handful of genes. However, the need for even greater food plant production looms. The

promise of C4 rice has resulted in one of the largest consortia of plant biologists pursuing a common goal. We optimistically take on this challenge, anticipating that advances in our understanding of plant metabolism, and C3 and C4 photosynthesis in particular, will better serve humanity in years to come.

Challenges and Bottlenecks

The engineering of C4 photosynthesis in rice represents one of the most complex genetic and developmental engineering challenges in modern plant science. Key obstacles include:

1. Complex Trait Integration

C4 photosynthesis involves over 20 genes working in a tightly coordinated manner across different cell types. Achieving correct localization, expression timing, and activity of these genes is a formidable task.

2. Anatomical Barriers

Kranz anatomy is not naturally present in rice. Reproducing it requires reprogramming developmental pathways to alter vein spacing and cell differentiation—processes not yet fully understood in monocots.

3. Metabolic Balance

Partial C4 metabolism can disrupt plant energy and carbon balance. Ensuring metabolic compatibility and avoiding unintended effects on growth and development is critical.

4. Field Validation

Engineering success in lab conditions must translate to real-world agricultural performance. Multi-location field trials under varying climates are necessary to test the viability of transgenic lines.

5. Regulatory and Public Acceptance

Like other genetically modified organisms (GMOs), C4 rice may face regulatory hurdles and public skepticism, particularly in countries with strict biotech laws.

Potential Impact and Implications

If successful, C4 rice could transform global agriculture:

- **Yield Increase:** Projected yield boosts of 30–50% could reduce land pressure and increase food availability.
- **Climate Resilience:** Enhanced performance under heat and drought conditions would make rice farming more sustainable.

- Environmental Benefits: Reduced need for nitrogen fertilizers and irrigation would lower greenhouse gas emissions and water pollution.
- Economic Growth: Smallholder farmers in Asia and Africa could benefit from increased productivity and profitability.

Furthermore, the knowledge gained from C4 rice research could be applied to other crops, enabling a broader revolution in agricultural biotechnology.

The Future of C4 Rice

Though the full implementation of C4 photosynthesis in rice may still be a decade or more away, the project is advancing steadily. Future efforts will likely focus on:

- Multi-gene stacking to combine anatomical and biochemical traits.
- Advanced gene editing (e.g., CRISPR) to fine-tune regulatory networks.
- Synthetic biology to design and assemble artificial C4 pathways.
- AI and machine learning to model and predict optimal gene expression patterns.
- Precision breeding to integrate C4 traits into elite rice varieties.

Governments, international organizations, and private foundations continue to invest in C4 rice as part of broader strategies for sustainable development and food security.

Conclusion

C4 rice represents a bold vision for the future of agriculture: a crop that not only produces more food with fewer inputs but also adapts to the stresses of a warming planet. By leveraging the tools of molecular biology, genetics, and systems engineering, scientists aim to rewrite the fundamental biology of rice to unlock its full potential. While many technical and societal challenges remain, the C4 Rice Project stands as a beacon of innovation and hope in the fight against hunger and environmental degradation.

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BAMBOO BRIQUETTES POWERING INDUSTRIES: GREENER FUEL FOR BRICK KILNS, BOILERS & BEYOND

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Abstract

Bamboo briquettes have emerged as a promising renewable fuel alternative for industrial applications such as brick kilns, boilers, and co-firing systems. With a high calorific value, low ash content, and cleaner emission profile compared to coal, bamboo-based briquettes offer both environmental and energy efficiency benefits. This review explores the chemical composition, emission characteristics, and mechanical properties of bamboo briquettes, emphasizing their suitability as a sustainable substitute for fossil fuels. Scientific findings show that bamboo's high lignin content facilitates natural binding during densification, resulting in durable briquettes with strong compression strength and uniform combustion behavior. Furthermore, the combustion of bamboo briquettes significantly reduces SO₂, NO_x, and PM_{2.5} emissions, contributing to improved air quality and reduced carbon footprints in industrial zones. These attributes position bamboo briquettes as a practical and eco-friendly energy solution for cleaner industrial operations.

Introduction

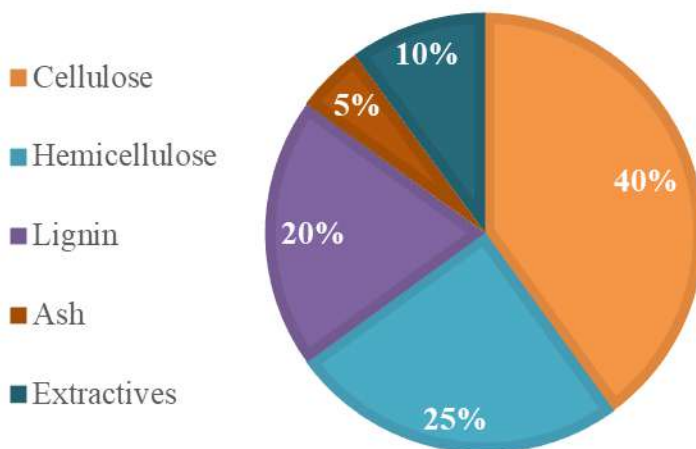
The demand for sustainable and environmentally friendly energy sources is increasing as industries around the world seek to reduce their dependence on fossil fuels. Biomass energy, which is derived from organic materials, offers a renewable alternative that can help meet this demand. Among various biomass resources, bamboo has gained attention due to its fast growth, high yield, and favorable fuel characteristics. Bamboo briquettes are made by compressing bamboo biomass into solid blocks that can be used as fuel in industrial applications such as brick kilns, boilers, and gasifiers. These briquettes have a high calorific value, low moisture and ash

content, and burn more cleanly than traditional fuels like coal. Bamboo contains natural binding agents, such as lignin, which allow it to be densified into briquettes without the need for chemical additives. Usage of bamboo briquettes can significantly reduce air pollutants such as sulfur dioxide (SO₂), nitrogen oxides (NO_x), and fine particulate matter (PM_{2.5}). This makes them a cleaner option for industries aiming to comply with environmental regulations and lower their carbon footprint. In addition, bamboo is considered a carbon-neutral resource because the carbon dioxide released during combustion is offset by the carbon absorbed during its rapid growth. This article discusses the chemical composition, emission characteristics, and mechanical strength of bamboo briquettes and highlights their potential as a clean, renewable fuel for industrial use.

Chemistry of bamboo

Bamboo biomass possesses an inherently favorable biochemical composition that is suitable for densified fuel production, particularly in the form of briquettes. Its structural components are dominated by **cellulose (40–50%)**, **hemicellulose (20–25%)**, and **lignin (20–30%)**, which together contribute to both its **high calorific value** and **natural binding properties** during briquetting. The lignin acts as a thermal binder during densification, eliminating the need for synthetic adhesives, while the cellulose and hemicellulose components contribute directly to energy yield during combustion. Calorific values reported for mature bamboo culms range from **16.5 to 19.5 MJ/kg**, which is comparable to high-grade hardwoods and significantly exceeds many agricultural residues (Patil *et al.*, 2023).

Fig.1. Typical chemical composition of bamboo



Other than its energy-rich biochemical profile, bamboo also exhibits **low inherent moisture content**, typically in the range of **8–12%** depending on harvest conditions and drying protocols. This ensures that minimal energy is lost in vaporizing water during combustion, thereby increasing thermal efficiency. The **ash content in bamboo biomass is relatively low**, often between 1-5% (**Rusch *et al.*, 2023**), which translates to less residual waste and reduced slagging or fouling in combustion systems. These properties also improve boiler longevity and reduce maintenance intervals in industrial applications.

Comparative elemental analysis shows that bamboo contains **higher fixed carbon** and lower nitrogen and sulfur content than many other biomass sources. This reduces the generation of environmentally harmful gases like NO_x and SO_x upon combustion. Thermogravimetric analysis (TGA) of bamboo has shown a **well-defined**, single-stage decomposition curve during pyrolysis, indicates uniform thermal degradation and energy release. This thermal behavior not only supports its suitability for direct combustion but also enhances its performance in thermochemical conversion pathways like gasification and pyrolysis.

Emission reduction: cleaner than coal

One of the most compelling arguments for the industrial adoption of bamboo briquettes lies in their significantly cleaner combustion profile compared to fossil fuels, particularly coal. Emissions associated with traditional thermal energy generation such as **sulfur dioxide (SO_2)**, **nitrogen oxides (NO_x)**, **carbon monoxide (CO)**, and **fine particulate matter (PM_{2.5})** are major contributors to atmospheric pollution, acid rain, and public health crises in industrial regions. Scientific assessments of bamboo combustion reveal that it contains **negligible sulfur** and **low nitrogen levels** (**Shezi and Kiambi, 2025**), resulting in far lower quantities of SO_2 and NO_x emissions during thermal degradation. For instance, co-firing studies involving bamboo and coal blends have shown that bamboo-rich mixtures can reduce SO_2 emissions by over **60%** and NO_x by nearly **40%**, depending on combustion conditions and feedstock purity (**Kwong *et al.*, 2007**).

In addition to its favorable elemental composition, the fine particle emissions generated from bamboo briquette combustion are also significantly reduced. Because bamboo burns more uniformly and produces minimal volatile organic compounds (VOCs), the amount of black carbon and respirable particulate matter released is substantially lower than in unprocessed biomass or coal combustion. This reduction is further enhanced when bamboo briquettes are

used in **controlled combustion systems**, such as **fluidized-bed boilers** or **zig-zag brick kilns**, which are specifically designed to optimize air-fuel ratios and combustion temperature. In such setups, total suspended particulate emissions can be reduced by up to **75%**, and combustion efficiency increased by **15–25%**, relative to conventional fixed-bed coal-fired systems.

Bamboo briquettes are considered **carbon-neutral** due to the closed carbon cycle inherent in biomass systems. The carbon dioxide released during combustion is offset by the CO₂ absorbed during the bamboo's rapid growth phase, especially in species harvested within three to four years. According to estimates from Patil *et al.* (2023), bamboo plantations can sequester **8–12 tonnes of CO₂ per hectare per year**, further improving their net carbon footprint when integrated into managed energy systems. When compared to coal, which emits around **2.4 kg of CO₂ per kg of fuel**, bamboo briquettes release less than half that amount on a life-cycle basis, especially when produced from processing residues that would otherwise decay and emit methane.

Emissions from bamboo briquettes can be further minimized through pre-combustion treatments such as torrefaction or controlled carbonization, which enhance the fuel's energy density and reduce volatiles. Densification itself also reduces fugitive dust during handling and transport, making it more suitable for use in urban or peri-urban industrial zones where emission regulations are stringent.

Mechanical strength and durability

In the context of industrial energy use, the physical integrity of briquettes plays an important role in determining their storage stability, transportation efficiency, feeding reliability, and overall combustion behavior. Bamboo briquettes, due to the intrinsic fiber structure and lignin-rich matrix of the bamboo plant, demonstrate **excellent mechanical durability** and compression resistance. These properties are vital for minimizing breakage, fines generation, and dust during handling, especially in large-scale industrial settings where automated feeding systems and bulk transport are involved. Scientific studies have shown that briquettes made from bamboo residues can exhibit **mechanical durability exceeding 95%** (Sanchez *et al.*, 2022), and **compression strengths ranging between 4.5–7.0 MPa**, depending on species, particle size, moisture content, and compaction pressure (Patil *et al.*, 2023).

The high lignin content of bamboo acts as a natural binder during the densification process. When exposed to the high pressure and moderate heat of any normal briquetting

(typically 120–150 MPa and 80–100 °C) (Sanchez *et al.*, 2022), lignin becomes plasticized, enabling strong inter-particle bonding without the need for external adhesives. This leads to briquettes that retain shape, resist cracking, and exhibit low expansion during combustion. The **bulk density** of bamboo briquettes ranges from **600–750 kg/m³**, which is notably higher than most loose biomass (100–300 kg/m³), translating to improved storage economy and better energy density per unit volume. Higher density also facilitates more efficient feeding in automated boiler systems, minimizing bridging or jamming in hopper-fed furnaces.

Drop resistance and abrasion tests further affirm the robustness of bamboo briquettes. Experimental data from trials involving mixed bamboo and sawdust feedstocks showed less than 5% fragmentation after drop impact from 1.5 m height, simulating real-world transport scenarios. These briquettes maintained structural integrity even after 30 days of open-air storage, provided that ambient humidity was controlled below 60%. This indicates that bamboo briquettes are not only mechanically resilient but also exhibit adequate shelf life and environmental stability for seasonal or long-term storage.

Table 1. Mechanical properties of bamboo briquettes compared to other biomass briquettes

Property	Bamboo briquettes	Sawdust briquettes	Rice husk briquettes	Coal
Compression strength (MPa)	3.5-5.2	2.1-3.8	1.8-3.0	8.0-10.5
Bulk density (kg/m ³)	900-1100	600-850	700-900	1200-1400
Durability	95-98	85-92	80-88	>99
Moisture content (%)	6-10	8-12	8-15	<5
Ash content (%)	2-4	3-6	10-15	5-20
Calorific value (MJ/kg)	18-20	15-18	14-17	24-28

Conclusion

Bamboo briquettes represent a significant advancement in clean and renewable industrial fuel technology. Their favorable biochemical makeup, particularly the high content of lignin and cellulose, allows for efficient energy release and strong mechanical properties without the need for external binders. With low sulfur and nitrogen content, bamboo briquettes substantially reduce harmful emissions compared to coal, aligning with global goals for pollution control and climate mitigation. Their high bulk density, durability, and combustion consistency make them suitable for automated systems and long-term storage. As industries increasingly prioritize sustainable practices, bamboo briquettes offer a scalable and eco-friendly energy alternative that bridges the gap between energy demand and environmental responsibility. Continued research and policy support can further accelerate their adoption across various industrial sectors.

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ROLE OF ADEQUATE HOUSING MANAGEMENT ON LIVESTOCK PRODUCTIVITY

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Abstract

Livestock farming is integral to India's agrarian economy, contributing significantly to rural livelihoods and national food security. However, the productivity of livestock is often compromised due to inadequate housing and management practices. This article explores the impact of proper housing management on livestock productivity in India, highlighting the importance of shelter design, environmental control, and management practices.. Adequate housing management is a cornerstone of effective livestock farming, influencing animal health, welfare, and productivity. This paper explores the multifaceted impact of housing on livestock, focusing on aspects such as ventilation, space, sanitation, and bedding materials. By examining various housing systems and their effects on livestock behavior and performance, the article underscores the importance of well-designed housing in enhancing productivity and sustainability in animal agriculture.

1. Introduction

India is home to the world's largest population of livestock, including cattle, buffaloes, sheep, goats, and poultry. The livestock sector plays a crucial role in the rural economy, providing employment, income, and nutritional security. However, the productivity of these animals is often hindered by suboptimal housing conditions. Inadequate housing can lead to stress, disease, and reduced performance, thereby affecting overall productivity. Therefore, understanding the role of housing management in livestock productivity is essential for sustainable development in the sector.

2. Importance of Adequate Housing for Livestock

2.1 Animal Welfare

Proper housing provides animals with protection from extreme weather conditions, predators, and diseases. It ensures comfort, safety, and freedom of movement, which are vital for their well-being. Adequate space and proper flooring reduce the risk of injuries and lameness, promoting better health and productivity.

2.2 Productivity Enhancement

Well-designed shelters can regulate temperature and humidity, reducing heat stress and improving feed intake and digestion. This leads to increased milk yield, weight gain, and reproductive efficiency. Additionally, clean and dry bedding materials minimize the risk of infections and diseases, further enhancing productivity.

2.3 Disease Control

Proper housing facilitates better management of manure and waste, reducing the spread of pathogens. Ventilation systems help in maintaining air quality, preventing respiratory diseases. Regular cleaning and disinfection protocols further contribute to disease control, ensuring a healthier livestock population.

3. Housing Systems in India

The most widely prevalent practice in this country is to tie the cows with rope on a Kutchra floor except some" organized dairy farms belonging to Government, co-operatives or Military where proper housing facilities exist It is quite easy to understand that unless cattle are provided with good housing facilities, the animals will move too far in or out of the standing space, defecting all round and even causing trampling and wasting of feed by stepping into the mangers. The animals will be exposed to extreme weather conditions all leading to bad health and lower production. Dairy cattle may be successfully housed under a wide variety of conditions, ranging from close confinement to little restrictions except at milking time.

3.1 Traditional Housing system

In rural India, many farmers still use traditional housing systems, such as kutchra (temporary) sheds made of thatch, mud, or bamboo. While these are cost-effective, they often lack proper ventilation, drainage, and insulation, leading to suboptimal conditions for the animals.

3.2 Conventional Barns or Stanchion Barns System

In this system of housing, the animals are confined together on a platform and secured at neck by stanchions or neck chain. The animals are fed as well as milked in the same barn. These barns are completely covered with roofs and the sidewalls are closed with windows or ventilator located at suitable places to get more ventilation and lighting. It is applicable for temperate and heavy rainfall region. The same type of housing can be utilized for tropical region with slight modification.

3.3 Loose Housing System

It is a system of housing in which animals are kept loose in an open paddock throughout the day and night except at the time of milking and treatment. In this system, shelter is provided along one side of open paddock under which animals can retire when it is very hot or cold or during rains. Common feed manger and water tank is provided and concentrates are fed at the milking time which is done in a separate milking barn or parlour in which cows are secured at milking time and are milked. The open paddock is enclosed by means of half walls or plain wire fences of convenient height.

4. Factors Influencing Housing Management

4.1 Climate

India's diverse climate affects housing requirements. In hot regions, shelters need to provide shade and cooling, while in colder areas, insulation and warmth are essential. Designing shelters that cater to local climatic conditions ensures animal comfort and productivity.

4.2 Economic Constraints

The financial limitations of farmers often restrict the adoption of modern housing systems. Government subsidies, low-interest loans, and training programs can help overcome these barriers, encouraging farmers to invest in better housing.

4.3 Knowledge and Awareness

Lack of awareness about the benefits of proper housing leads to the continuation of traditional practices. Extension services and training programs can educate farmers on the importance of housing and provide guidance on constructing and maintaining shelters.

6. Government Initiatives

6.1 National Programme for Dairy Development (NPDD)

The NPDD aims to promote dairy farming by providing financial assistance for infrastructure

development, including housing. It encourages the construction of modern dairy units with proper housing facilities.

6.2 Rashtriya Gokul Mission

This mission focuses on the development and conservation of indigenous bovine breeds. It includes provisions for setting up modern gaushalas (cow shelters) with adequate housing and management practices.

6.3 State-Level Schemes

States like Uttar Pradesh, Haryana and Madhya Pradesh have launched initiatives to improve livestock housing. For instance, Haryana has increased funding for cow shelters and provides subsidies for indigenous cows.

7. Challenges and Recommendations

7.1 Challenges

- **High Initial Costs:** The expense of constructing modern shelters is a significant barrier.
- **Lack of Skilled Labor:** There is a shortage of trained personnel to design and build appropriate housing.
- **Cultural Practices:** Traditional beliefs and practices may resist changes in housing systems.

7.2 Recommendations

- **Subsidies and Financial Support:** Government should provide financial assistance to farmers for constructing modern shelters.
- **Training and Extension Services:** Implement training programs to educate farmers on the benefits and construction of proper housing.
- **Community Involvement:** Engage local communities in the planning and implementation of housing projects to ensure cultural acceptance.

Conclusion

Adequate housing management plays a pivotal role in enhancing livestock productivity in India. By providing animals with comfortable, clean, and safe environments, farmers can improve health, welfare, and performance. While challenges exist, concerted efforts from the government, NGOs, and the farming community can lead to significant improvements in livestock housing and productivity.



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BANANA LEAF PACKAGING: A SUSTAINABLE ALTERNATIVE FOR SHELF-LIFE EXTENSION IN FRESH PRODUCE

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Abstract

This study explores banana leaf-based packaging as a sustainable alternative to plastic for extending the shelf life of fresh produce. High-respiration vegetables—tomatoes and okra—were packaged using steamed banana leaves, polyethylene bags, and left unpackaged as control. After 7 days of ambient storage ($25 \pm 2^\circ\text{C}$), banana leaf packaging resulted in the lowest weight loss (9.4% in tomatoes, 11.1% in okra), highest visual quality scores (7.8 and 7.2), and lowest microbial load (2.1 log CFU/g). Firmness and vitamin C retention were significantly higher than in plastic or control samples. Banana leaves, due to their antimicrobial properties, breathability, and biodegradability, provide a promising eco-friendly packaging alternative for fresh produce.

Keywords: Banana leaves, sustainable packaging, plastic alternative, microbial load, post-harvest quality, shelf life.

Introduction

The growing concern over plastic pollution and its environmental consequences has prompted global efforts to identify sustainable alternatives to conventional plastic packaging. Single-use plastics, widely utilized in the food industry, pose a significant ecological threat due to their persistence in the environment and limited recycling infrastructure (Jambeck et al., 2015). In response, research has turned toward biodegradable materials derived from renewable sources, with plant-based packaging emerging as a promising solution. Among these, banana leaves offer a natural, cost-effective, and environmentally friendly packaging material with several functional properties conducive to post-harvest preservation.

Banana leaves have long been used in traditional practices across Asia and Africa for wrapping and storing food due to their strength, pliability, and microbial resistance. Recent studies highlight the biochemical constituents of banana leaves—such as polyphenols, flavonoids, and essential oils—that contribute to their antimicrobial and antioxidant activities (Singh et al., 2021). These natural compounds help maintain food safety and extend shelf life without the need for synthetic additives. Furthermore, the structure of banana leaves allows for gas exchange, helping to moderate humidity and reduce anaerobic conditions that often lead to spoilage in sealed plastic environments.

High-respiration vegetables like tomatoes and okra are particularly vulnerable to rapid degradation under improper packaging, often exhibiting water loss, microbial contamination, and nutrient deterioration. Packaging solutions that are breathable, antimicrobial, and biodegradable could significantly improve the storage quality of these perishables. While prior research has explored biopolymer-based edible coatings (Galus & Kadzińska, 2015) and plant-extract-enriched films (Ramos et al., 2013), fewer studies have rigorously evaluated banana leaves as a primary packaging substrate under controlled experimental conditions. This study evaluates the effectiveness of banana leaf packaging, both untreated and thermally treated, in preserving the post-harvest quality of tomatoes and okra. The investigation includes comparisons with conventional polyethylene packaging and unpackaged controls, measuring parameters such as weight loss, visual quality, microbial load, firmness, and nutrient retention. The broader objective is to assess banana leaves as a viable alternative to plastic, capable of enhancing sustainability while maintaining or improving post-harvest performance.

Materials and Methods

Fresh banana leaves were collected from local farms, cleaned thoroughly to remove dust and debris, and then sterilized using a 1% sodium hypochlorite solution for 2 minutes followed by rinsing with distilled water. The leaves were cut into sheets of uniform size (20 cm × 20 cm) and subjected to two treatments: untreated (natural state) and thermally treated (light steaming at 70°C for 5 minutes) to improve flexibility and microbial safety. These treated banana leaves were then air-dried at ambient temperature for 1 hour before use as packaging. Packaged commodities included tomatoes and okra—both high-respiration vegetables—selected due to their perishability. Each product was packaged in three types of material: banana leaf packaging, conventional plastic packaging (polyethylene bags), and control (no packaging). All packaged

samples were stored at $25 \pm 2^{\circ}\text{C}$ and 60% RH for 7 days. Observations were recorded daily, focusing on weight loss, visual quality (scored on a 9-point hedonic scale), microbial load (CFU/g), and shelf life (days until unmarketable). Nutritional parameters including vitamin C content, firmness, and total soluble solids (TSS) were also assessed on Day 0 and Day 7 using standard protocols (AOAC, 2005).

Results and Discussion

The use of banana leaf packaging significantly impacted the preservation of visual quality and shelf life in tomatoes and okra compared to both plastic packaging and the unwrapped control. Visual quality scores on Day 7 were highest in banana leaf-wrapped produce (7.8 for tomatoes and 7.2 for okra) compared to plastic-packaged (6.5 and 6.1) and control samples (5.3 and 4.9). This indicates that the natural **microenvironment** maintained by banana leaves helps reduce moisture loss and delay senescence. The average weight loss was also lower in banana leaf packaging (9.4% for tomatoes and 11.1% for okra) than in plastic (14.8% and 15.3%) and control (18.5% and 20.1%), suggesting reduced transpiration and water vapor loss due to the breathable structure of banana leaves. Microbial analysis showed reduced CFU counts on the surface of produce stored in banana leaves, likely due to the antimicrobial compounds naturally present in the leaves such as polyphenols and terpenoids (Singh et al., 2021). Tomato samples wrapped in banana leaves exhibited a microbial count of 2.1 log CFU/g compared to 3.8 log CFU/g in plastic and 4.6 log CFU/g in controls. **Firmness** retention was superior in banana leaf-treated samples, retaining 78% of original firmness in tomatoes and 74% in okra. Furthermore, vitamin C degradation was less pronounced in banana leaf packaging (retaining 86% of initial vitamin C in tomatoes), possibly due to the moderated oxidative stress within the packaging microclimate. Total soluble solids showed minor changes across all treatments.

Overall, banana leaf packaging not only maintained better freshness and visual appeal but also provided environmental benefits due to biodegradability. Unlike polyethylene, banana leaves decompose naturally and do not contribute to plastic pollution, making them a viable packaging alternative. Their antimicrobial properties, breathability, and low-cost availability enhance their utility for small-scale farmers and organic producers. These findings are consistent with those of Gnanasekaran et al. (2019), who reported that banana leaf-based wraps extended shelf life and reduced spoilage rates in cucumbers and leafy greens. The study demonstrates that

banana leaves offer a promising, sustainable replacement for single-use plastics in fresh produce packaging.

Conclusion

Banana leaves present a viable, eco-friendly alternative to plastic packaging in the fresh produce industry. This study demonstrated their effectiveness in extending the shelf life of high-respiration vegetables by minimizing moisture loss, microbial growth, and nutrient degradation. Their natural antimicrobial properties, biodegradability, and affordability make them especially suitable for smallholder and organic farmers. However, to facilitate large-scale adoption, future research should address durability under variable humidity, mechanical strength for long-distance transportation, and consumer acceptability. Integrating banana leaf packaging with modern supply chain logistics can enhance sustainability in fresh produce marketing while reducing reliance on non-biodegradable plastics.

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EDIBLE BIOPOLYMER COATINGS WITH BOTANICAL EXTRACTS: ENHANCING SHELF LIFE OF FRUITS AND VEGETABLES

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Introduction

Edible coatings are thin, consumable layers applied to the surface of food products, especially fruits and vegetables, to protect them from spoilage and extend their shelf life. These coatings serve as semi-permeable barriers that regulate the exchange of moisture, gases, and solutes, thereby reducing water loss, delaying ripening, and inhibiting microbial growth. The primary materials used to create these coatings are biopolymers, which are naturally derived, biodegradable, and safe for human consumption. Biopolymers include polysaccharides like starch, cellulose, and alginate, which form strong, breathable films; proteins such as gelatin, casein, and whey, which provide excellent oxygen barrier properties; and lipids like waxes and fatty acids, effective in preventing moisture loss. Often, these biopolymer-based coatings are enhanced with natural additives like essential oils or plant extracts to offer additional antioxidant and antimicrobial protection. With increasing consumer demand for eco-friendly and chemical-free food preservation methods, biopolymer-based edible coatings are gaining popularity as a sustainable alternative to synthetic packaging. They not only help maintain the freshness and nutritional quality of food but also reduce post-harvest losses and environmental impact.

Biopolymer-based edible coatings provide a protective barrier against physical damage, moisture loss, and gas exchange; however, they often lack strong antimicrobial and antioxidant properties on their own. This limitation necessitates the incorporation of natural additives, particularly those derived from plants, to enhance the functional properties of the coatings. Natural extracts, such as essential oils, herbal extracts, and bioactive plant compounds (e.g.,

phenolics, flavonoids, tannins), can significantly improve the performance of edible coatings by providing antimicrobial, antifungal, and antioxidant activities. These bioactives help control spoilage microorganisms, reduce oxidation of nutrients and fats, and preserve the color, texture, and flavor of fresh produce. Unlike synthetic preservatives, which may raise health or regulatory concerns, natural additives are generally recognized as safe (GRAS) and are more acceptable to consumers who prefer “clean-label” or chemical-free food options. Moreover, using plant-based additives enhances nutritional and therapeutic value, such as anti-inflammatory or immune-boosting properties. Therefore, enriching edible coatings with natural compounds not only improves food safety and shelf life but also aligns with sustainable, eco-friendly, and health-conscious trends in modern food preservation.

A wide variety of plant extracts are commonly used to enrich biopolymer-based edible coatings due to their rich content of bioactive compounds such as phenolics, flavonoids, tannins, alkaloids, and essential oils. These compounds offer powerful antimicrobial, antifungal, and antioxidant effects, making them ideal natural additives for food preservation. For instance, clove, cinnamon, and oregano extracts contain essential oils with strong antimicrobial properties that inhibit spoilage bacteria and fungi. Green tea extract is rich in catechins, effective antioxidants that help delay oxidative browning and lipid peroxidation in fresh produce. Neem and turmeric extracts are recognized for their antibacterial and anti-inflammatory properties, while rosemary and thyme extracts provide both microbial inhibition and oxidation control. These extracts not only protect food but may also offer health benefits due to their nutraceutical properties. Including such plant extracts in edible coatings provides a dual advantage—preserving quality and extending the shelf life of fresh foods while also promoting safety and nutritional enhancement without relying on synthetic chemicals. The effectiveness of each extract depends on its concentration, the type of biopolymer used, and the nature of the food product, making it essential to optimize formulations for various applications.

Preparing biopolymer-based edible coatings

Preparing biopolymer-based edible coatings involves several key steps to ensure a uniform, stable, and effective coating formulation. First, the biopolymer—such as starch, alginate, gelatin, or chitosan—is dissolved or dispersed in a suitable solvent, typically water or an ethanol-water mixture, under controlled heating and stirring conditions to form a homogeneous solution. To improve the flexibility and mechanical strength of the resulting film,

a plasticizer like glycerol, sorbitol, or polyethylene glycol is added. If the coating is to be functionalized, natural additives such as essential oils, plant extracts, or antimicrobial agents are incorporated into the solution, either directly or in nanoemulsified form to enhance their stability and effectiveness. The resulting solution is then applied to the surface of the food product using methods such as dipping, spraying, brushing, or coating with rollers, depending on the food type and the desired coating thickness. After application, the coated product is dried under ambient or controlled conditions to form a thin, uniform film. Throughout the process, parameters like pH, viscosity, temperature, and drying time are carefully optimized to ensure proper adhesion, transparency, and functionality of the final coating. Advanced techniques may also involve layer-by-layer assembly or nanoencapsulation to improve the controlled release of active ingredients, making these coatings more efficient for commercial applications.

Biopolymer-based edible coatings

Biopolymer-based edible coatings have been widely applied to various fruits and vegetables to enhance their shelf life, appearance, and safety during storage and transportation. These coatings are particularly beneficial for perishable produce such as tomatoes, cucumbers, bell peppers, apples, bananas, strawberries, and mangoes, which are susceptible to rapid moisture loss, enzymatic browning, microbial spoilage, and oxidative degradation. Once applied—usually by dipping, spraying, or brushing—the coating forms a thin, invisible, and breathable film over the surface of the produce. This film acts as a semi-permeable barrier, controlling the exchange of gases like oxygen and carbon dioxide, thereby slowing respiration rates and delaying ripening and senescence. Additionally, it reduces moisture loss, helping to maintain firmness, juiciness, and weight of the fruits or vegetables. When enriched with natural additives like plant extracts or essential oils, the coating also provides antimicrobial protection, reducing surface contamination by spoilage bacteria and fungi. For example, chitosan coatings with clove oil have been found effective in extending the freshness of strawberries, while aloe vera and starch-based coatings help maintain the quality of tomatoes. These applications not only preserve sensory attributes such as color, texture, and flavor but also minimize post-harvest losses, making edible coatings a valuable technology in modern post-harvest handling and supply chain management.

The preservation effect of biopolymer-based edible coatings is achieved through a combination of physical, chemical, and biological mechanisms that work together to extend the shelf life of fruits and vegetables. First, the physical barrier created by the coating reduces the

rate of respiration by limiting the diffusion of gases such as oxygen and carbon dioxide. This helps delay ripening, senescence, and enzymatic browning. At the same time, the coating slows down moisture loss, crucial for maintaining firmness, texture, and weight, especially in high-respiration produce. Second, when the coating is enriched with natural plant extracts or essential oils, it acquires antimicrobial properties that inhibit the growth of spoilage-causing and pathogenic microorganisms. These bioactive compounds disrupt microbial cell membranes, alter their metabolism, and inhibit biofilm formation. Third, many plant extracts are rich in antioxidants like phenolic compounds and flavonoids, which help neutralize reactive oxygen species (ROS) and reduce lipid peroxidation—a major cause of oxidative damage in fresh produce. These antioxidants also suppress the activity of enzymes such as polyphenol oxidase (PPO) and peroxidase (POD), responsible for browning and degradation. Collectively, these mechanisms help maintain the visual appeal, nutritional value, and microbial safety of the coated produce.

The multifunctional nature of the coatings enables them to act as smart, active packaging systems that respond to both internal and external changes during storage. Biopolymer-based edible coatings offer several significant advantages over conventional synthetic coatings and plastic-based packaging, particularly regarding safety, sustainability, and functionality. First and foremost, biopolymer coatings are derived from natural, renewable sources such as plants, animals, or microorganisms, making them biodegradable and environmentally friendly. In contrast, synthetic coatings often contribute to plastic waste and environmental pollution. Secondly, edible coatings are non-toxic and safe for human consumption, eliminating the need for removal before eating, unlike synthetic waxes or films, some of which may raise health concerns. These coatings can also be functionalized with natural plant extracts, essential oils, and antioxidants to provide additional antimicrobial and antioxidant benefits—something not typically achievable with inert synthetic materials. Additionally, they allow for gas permeability control (oxygen and carbon dioxide), which helps maintain the quality and shelf life of fresh produce without creating anaerobic conditions that could lead to spoilage. From an economic and consumer standpoint, edible biopolymer coatings appeal to the growing demand for clean-label, organic, and chemical-free food products.

Moreover, since many of these materials (like starch or chitosan) are readily available and cost-effective, they offer a practical and scalable solution for both small-scale farmers and

the food industry. Thus, biopolymer-based coatings not only effectively preserve food quality but also align with global efforts toward sustainable and health-conscious food packaging technologies. Despite their many benefits, biopolymer-based edible coatings face several limitations and challenges that can hinder their large-scale commercial application. One major challenge is the inconsistent performance of coatings depending on the type of produce, environmental conditions, and coating composition. For instance, some biopolymers like starch or proteins have poor water resistance, making them less effective in high-humidity conditions or for products with high moisture content. Additionally, coatings enriched with essential oils or plant extracts can sometimes cause undesirable changes in taste, aroma, or appearance, which may affect consumer acceptance. Another significant limitation is the lack of standardization in formulation and application techniques; variations in concentration, drying time, or method of application (dipping, spraying, brushing) can result in non-uniform coating layers that reduce efficacy.

Biopolymer films

Mechanical properties of biopolymer films, such as brittleness or poor flexibility, can also lead to cracking or flaking during handling and storage. From a technological standpoint, the scalability of these coatings remains a challenge, especially in rural or resource-limited settings, due to the need for specialized equipment, quality control, and skilled labor. Moreover, regulatory approval for new bioactive compounds or plant extracts added to coatings can be a time-consuming and costly process. Finally, there is still a need for long-term shelf-life studies and market awareness, as many consumers and producers are unfamiliar with these novel, sustainable packaging alternatives. Addressing these challenges through improved formulation, cost-effective technologies, and awareness campaigns will be critical for the broader adoption of edible coatings in the food industry.

Cutting-edge research in edible coatings has introduced a variety of advanced strategies and materials to enhance functionality, durability, and controlled release of bioactive agents. One prominent approach is nanoencapsulation and nanoemulsification, which improve the dispersion, stability, and bioavailability of plant extracts and essential oils—reducing volatility and preventing interactions with polymer matrices. For instance, nanoemulsions of curcumin or green tea catechins encapsulated within chitosan or alginate films exhibit improved antimicrobial and antioxidant effects. Another trend involves layer-by-layer (LbL) assembly, where alternating

layers of biopolymers (e.g., chitosan, pectin, or alginate) create multifunctional, multilayer films that offer precisely tuned permeability, mechanical strength, and active-agent release profiles. Researchers are also exploring smart coatings that incorporate pH- or ethylene-sensitive dyes, enabling real-time freshness indicators by changing color as produce ripens or spoils. Additionally, active-release systems using microcapsules or microgels are being developed to gradually release antimicrobials when needed, extending protection over longer storage periods. Composite coatings that blend nanofillers (like cellulose nanocrystals, nanoclays, or nanosilver) with biopolymers are showing enhanced barrier properties and strength. Lastly, growing interest in sustainable sourcing has driven work on biopolymers derived from food-industry waste, such as fruit peels or plant residues, and the integration of functional food additives (vitamins, probiotics) into coatings.

These innovations reflect a move toward smarter, greener, and more efficacious edible packaging solutions that align with circular economy and clean-label trends. In conclusion, biopolymer-based edible coatings enriched with natural plant extracts represent a promising, sustainable alternative to conventional synthetic packaging, particularly for preserving the quality and extending the shelf life of fresh fruits and vegetables. These coatings not only serve as physical barriers to moisture loss and gas exchange but also deliver functional benefits such as antimicrobial and antioxidant protection when formulated with bioactive compounds. However, despite their advantages, several practical challenges remain to overcome, including limited water resistance, variability in performance, consumer acceptance, and scalability for industrial use. The outlook is highly optimistic, driven by growing consumer demand for clean-label, eco-friendly food preservation methods and increasing regulatory pressure to reduce plastic waste.

Conclusion

Emerging innovations such as nano-enabled delivery systems, smart coatings with freshness indicators, and multilayered or composite films are opening new frontiers in coating technology. Additionally, the use of agricultural waste as a source of biopolymers and functional additives can enhance sustainability while reducing costs. With continued research, optimization of formulations, standardization of application techniques, and industry collaboration, edible coatings have the potential to play a key role in reducing post-harvest losses, improving food safety, and advancing the global movement toward greener packaging systems soon.

METAGENOMICS – AN INTRODUCTION

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Introduction

About thirty years ago, in 1986, Pace and collaborators proposed, for the first time, the revolutionary idea of cloning DNA directly from environmental samples to analyze the complexity of natural microbial populations. The adopted strategy was based on shotgun cloning of 16S rRNA genes using purified DNA from natural samples.

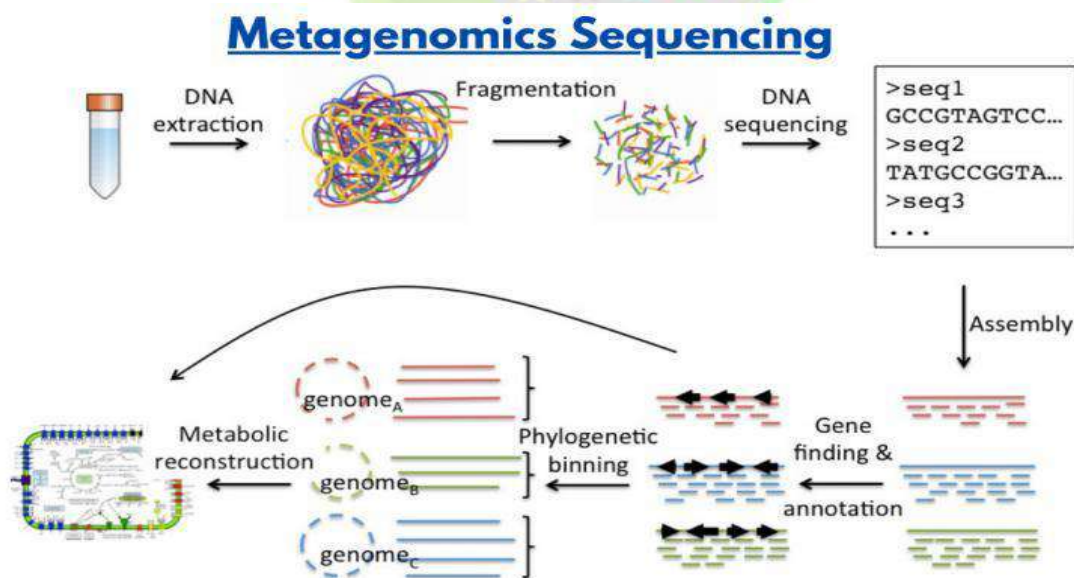


Fig.1. Metagenomics sequencing for identification

At that time, authors stressed that although the DNA was originated from a mixed population of microorganisms, the methodology allowed the recovery and subsequent sequencing of individual rRNA genes. Thus, by evaluating complete or partial rRNA sequences, the composition of the original microbial populations could be retrieved.

Currently, metagenomics is subdivided into two major approaches, which target different aspects of the local microbial community associated with a determined environment. In the first one, the so-called structural metagenomic approach, the main focus is to study the structure of the uncultivated microbial population, which can be expanded to other properties, such as the reconstruction of the complex metabolic network established between community members . In this sense, the microbial community structure can be defined as the population composition and its dynamics in a specific ecosystem, in response to selective pressures and spatiotemporal parameters.

The study of the community structure allows a deeper understanding about the relationships between the individual components that build a community and is essential for deciphering ecological or biological functions among its members . In a different manner, the functional metagenomic approach aims to identify genes that code for a function of interest, which involves the generation of expression libraries with thousands of metagenomic clones followed by activity-based screenings

Milestones in Metagenomics

Since then, a large amount of data has been generated using metagenomic approaches and impacting different areas of high applicability in our society . Here, we highlighted the main milestones in metagenomic studies that defined the field in distinct contexts. Although many of the advances in the field can be credited to novel sequencing approaches and the development of new computational methodologies to analyze the generated data, in this review, we have focused on highlighting biological discoveries through metagenomics rather than describing these more technical strategies, which have been addressed in recent reviews.

Genomic and Taxonomic Novelties in Environments

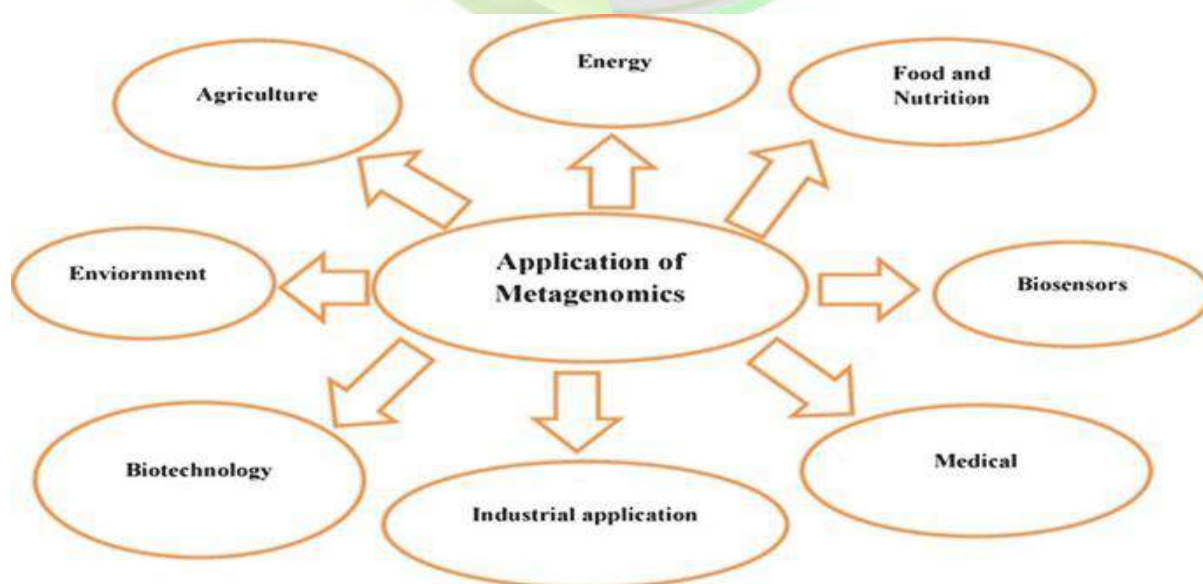
Ever since the proposal of using molecular markers such as 16S (or 18S) rRNA for comparing species similarity, in the late 1970s, followed by the outlining of a third “urkingdom” (the Archaeobacteria), our knowledge of organism relatedness has taken a great leap forward. Taxonomic classification started to rely on a “comparative approach that can measure the degree

of difference in comparable structures,” which not only allowed a more resolved phylogeny and a less biased organization based on the Prokaryotae versus Eukaryotae dichotomy but also made it possible to better understand how life on earth has come to be. In this context, metagenomic approaches have been used to generate data of novel genomes from otherwise uncultivated organisms, deepening the framework of genomic tools available for comparison and study.

The shotgun sequencing of the Sargasso Sea waters, by Venter and colleagues in 2004, is one of the most illustrative examples of how metagenomics are a feasible way to accumulate genomic knowledge. In this study, Venter and collaborators have recovered almost 1.5 Gbp of microbial DNA sequences from microbial populations of three marine sites using enmasse whole genome shotgun sequencing from filtered sea water. This leads to the finding of almost 70 thousand novel genes among the roughly 1.2 million genes by ORF (open reading frame) identification and alignment of the putative protein products. Among the main findings, the researchers described a novel ammonia oxidation pathway uninhibited by UV light, putative genes for trace metal resistance such as arsenate and copper, and, additionally, up to 782 new proteorhodopsin-like receptors genes.

Application of metagenomics

Metagenomics is the study of the structure and function of entire nucleotide sequences isolated and analyzed from all the organisms (typically microbes) in a bulk sample. Metagenomics is often used **to study a specific community of microorganisms, such as those residing on human skin, in the soil or in a water sample.**



NITROUS OXIDE EMISSION FROM AGRICULTURAL FIELDS AND ITS MITIGATION STRATEGIES

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Introduction

Nitrous oxide (N_2O) has a global warming potential 265 times that of carbon dioxide, over a 100-year timescale. Consequently, in spite of its very small concentration in the atmosphere, its contribution to global warming makes it the third most important of the long-lived greenhouse gases. Until recently, this position was held by the chlorofluoro-compound CFC-12, a substance best-known for its destruction of stratospheric ozone rather than for its role as a greenhouse gas. However, the atmospheric burden of CFC-12 (together with other CFCs) is now declining with the implementation of the 1989 Montreal Protocol, whereas that of N_2O is increasing (Smith, 2017). The main sources of nitrous oxide are agriculture, fossil fuel combustion, biomass burning, atmospheric deposition and human sewage. Therefore, it is probable that N_2O will become the dominant ozone-depleting substance in Earth's atmosphere in near future. Globally, agricultural N_2O emissions have increased by nearly 17 % from 1990 to 2005, and are projected to increase 35-60 % by 2030 due to increased nitrogen (N) fertilizer use.

Effect of N_2O on human health

- Blurred vision
- Unusual tiredness or weakness
- Bluish lips or skin
- Dizziness
- Tightness in the chest

- Trouble in breathing

Main processes responsible for N₂O production and emission

Nitrous oxide production in soil results predominantly from a range of microbial processes: nitrification, denitrification and nitrifier denitrification. The two processes that are generally regarded as most important for N₂O production are autotrophic nitrification, involving ammonia-oxidizing *Nitrosomonas* and *Nitrosospira* bacteria, and heterotrophic denitrification, brought about by a wide range of bacteria, together with some archaea and fungi (Baggs & Phillipot, 2010). Nitrification is an aerobic process that depends on the availability of ammonia and oxygen whereas denitrification is an anaerobic process controlled by the availability of carbon (C), nitrate and the oxygen supply, which is very variable in time and space. In nitrifier denitrification, the oxidation of ammonia to nitrite is followed by the reduction of nitrite to N₂O; the entire process is carried out by ammonia-oxidizing bacteria.

Measurement of nitrous oxide emission from soil.

Nitrous oxide sample is collected using static or closed chamber technique and analysed using gas chromatography. Gas samples are collected using Plexiglas chambers (50 cm X 20 cm X 100 cm) placed on aluminium channels (60 cm X 30 cm) inserted permanently in the soils. To make the arrangement airtight, water was poured into the channels. Boxes will be kept on the plants for 2 hours continuously during the daytime (10:00– 12:00 hours) on the days of sampling. Gas samples are collected through sampling ports fitted at the top of the chamber using gas tight syringes. The samples were transferred to 15 ml vacutainer tubes, brought to the laboratory and analyzed for N₂O by a gas chromatograph (Hewlett-Packard, Series 5590), fitted with Porapack-N column and electron capture detector (ECD). Nitrogen was used as carrier gas with a flow rate of 20 ml min⁻¹. Oven, injector and detector temperatures were set at 50, 120, 350 °C, respectively. A sample of 500 ppb N₂O was used as standard. Total emissions of N₂O–N during the entire period were estimated by multiplying the average emissions of two consecutive sampling dates by the number of days in between.

Ways to reduce N₂O emission

- Use less nitrogen fertiliser. This only makes sense if more fertiliser is being added than is needed. Use soil testing and visual signs to manage nitrogen fertiliser rates.
- Use split applications of nitrogen fertilisers. This increases the efficiency of use by plants, allowing less nitrogen to be lost to the atmosphere or leach.

- This option is particularly suited to waterlogged sites.
- Use legume crops or pastures in the rotation instead of nitrogen fertiliser. More of the nitrogen is in the form of organic matter which is released more slowly and is used more effectively by growing plants. Use minimum tillage for cropping. This minimises organic matter breakdown and the release of nitrous oxide and nitrogen gas.
- Prevent waterlogging. Under waterlogged conditions, nitrate can be denitrified by soil bacteria to form nitrous oxide and nitrogen gas.
- Use nitrification inhibitors. These work by reducing nitrification which reduces nitrate leaching and the production of nitrous oxide. These inhibitors can be mixed with nitrogen fertilisers or applied separately.

Conclusion

In future, N₂O emissions are likely to increase due to increased use of N fertilizer, because of the need to feed increasing populations. Hence, nitrogen fertiliser management studies, use of nitrification inhibitors or slow releasing N fertilizers which improves N use efficiency will be useful for developing strategies for mitigation of N₂O emissions at the national level and can further contribute to global databases of N₂O emissions.

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METHOD TO CONTROL POST HARVEST LOSSES IN VEGETABLES

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Introduction

Post-harvest loss is one of the leading issues threatening the food value chain. According to recent studies, a significant increase is observed in vegetable losses, so it is important to eliminate these losses to sustain the world's population. This blog will discuss the nature and causes of post-harvest losses and how to prevent them. Post-harvest losses begin in the field at the time of harvest and continue after harvest in the grading and packing process, during storage, transportation, and wholesale and retail markets. Numerous losses happen due to inadequate infrastructure, a lack of expertise, poor management, a broken market, or just the negligence of farmers.

CAUSES OF POST-HARVEST LOSSES OF VEGETABLES:

HARVESTING:

For vegetables, ripening at harvest time is the main factor that determines the product quality and the shelf life. However, some farmers can harvest immature crops due to economic reasons. Early harvesting reduces the nutritional and economic value of crops. In some cases, whole products can be lost because they are not suitable for consumption. Harvest techniques can also cause losses. The losses increase when easily perishable foods such as vegetables are exposed to more than one treatment. At the same time, farmers may not have storage containers

at the harvesting or after harvesting stages. This leads to mechanical damage during harvesting of vegetables and root and tuber plants, resulting in certain losses. Incorrect application in cultural practices such as frost, hail, drought, excessive rainfall, diseases, physiological disorders, plant nutrition, plant protection, irrigation, fertilization, and pruning in the preharvest period cause vegetable losses. During the harvesting period; incorrect estimation of harvesting time, harvesting at the wrong time, improper application of harvesting practices.

STORAGE

A cold chain is a continuous supply of a product from production to consumption at a certain temperature. Continuous cold chain in perishable food ensures that the product reaches the consumer without deterioration. Effective cold chain management starts with pre-cooling and continues with cold storage, cold transport and refrigerated display cases. The International Refrigeration Institute (IIR) calculated that in developing countries 23% of the perishable foods were spoiled because of not being used the cooler, After application of some treatments such as cleaning, sorting, and packaging on post-harvest products, it may be necessary to store the products in periods ranging from a few hours to a few months. By storing products, time management can be improved, and marketing and consumption can be done leisurely. Of course this situation is valid when the storage operation is valid when the storage operation is carried out under suitable conditions; otherwise, serious losses may occur in products.

TRANSPORTATION

Since transportation places a certain period of time between production and consumption, it can be one of the main causes of losses, especially for fresh products. In developed countries, delivery of perishable foods with refrigerated vehicles is a standard practice. In developing countries, the absence of appropriate means of transport, poor roads and inefficient logistics management prevent perishable foods from being properly preserve. In addition, loading and unloading operations are carried out in these countries by unskilled and uneducated workers who generally do not carry products carefully. This causes mechanical damage in agricultural products.

IMPROPER PACKAGING

Farmers sell their produce in fresh markets or in wholesale markets. This type of market handling of fresh produce greatly reduces its shelf life if it is not sold quickly. Packaging is an important factor in reducing losses, as well as extending the shelf life of fresh vegetables.

Therefore, one of the major reasons that vegetables are lost at post-harvest stages is improper packaging and use of unsuitable packaging material. Poor quality packaging materials cannot adequately protect the fresh produce from damages and can even accelerate spoilage of fresh produces. According to a study carried out in some countries in Sub-Saharan Africa and South Asia, 46 % of horticultural crops were packed in cloth bundles or large sacks, 31% of them were packed in open baskets and 8 % had no package at all.

BIOLOGICAL

Biological causes of deterioration include respiration rate, ethylene production and action, rates of compositional changes (associated with color, texture, flavour, and nutritive value), mechanical injuries, water stress, sprouting and rooting, physiological disorders, and pathological breakdown. The rate of biological deterioration depends on several environmental factors, including temperature, relative humidity, air velocity, and atmospheric composition (concentration of oxygen, carbon dioxide, and ethylene), and sanitation procedures.

CHEMICAL

Many of the chemical constituents naturally present in stored foods spontaneously react causing losses of color, flavour, texture and nutritional value. One such reaction is the 'maillard relation' that causes browning and discoloration in dried fruits and other products. There can also be harmful chemicals such as pesticides or obnoxious chemicals such as lubricating oil.

TEMPERATURE

In general, the higher the temperature the shorter the storage life of horticultural products and the greater the amount of loss within a given time, as most factors that destroy the produce or lower its quality occur at a faster rate as the temperature increases.

HUMIDITY

There is movement of water vapour between stored food and its surrounding atmosphere until equilibrium of water activity in the food and the atmosphere. A moist food will give up moisture to the air while a dry food will absorb moisture from the air. Fresh horticultural products have high moisture content and need to be stored under conditions of high relative moisture loss and wilting (except for onions and garlic). Dried or dehydrated products need to be stored under conditions of low relative humidity in order to avoid adsorbing moisture to the point where mold growth occurs.

STRATEGIES OF REDUCING POST-HARVEST LOSSES IN VEGETABLES

HARVESTING

Harvesting should be carried out as carefully as possible to minimize mechanical injury such as scratches, punctures and bruises to the crop. The time of the day when harvesting is done also affects produce quality and shelf-life. In general, harvesting during the coolest time of the day (early morning) is desirable; the produce is not exposed to the heat of the sun and the work efficiency of the harvesters is higher. If harvesting during the hotter part of the day cannot be avoided, the produce should be kept shaded in the field to minimize product weight loss and wilting.



HANDLING

Mechanical injury provides sites for pest attack and increases physiological losses. Therefore, avoid mechanical injury to the crop while handling. Because of their soft texture, all horticultural products (vegetables) should be handled gently to minimize bruising and breaking of the skin. The skin of horticultural products is an effective barrier to most of the opportunistic bacteria and fungi that cause rotting of the tissues. Breaking of the skin also stimulates physiological deterioration and dehydration. Reducing the number of times the commodity is handled reduces the extent of mechanical damage.

SORTING AND CLEANING

Systematic sorting or grading coupled with appropriate packaging and storage, will extend shelf life, maintain wholesomeness, freshness, and quality, and substantially reduce losses and marketing costs. Sorting is done to separate poor produce from good produce, and further classify the good produce based on other quality parameters like size.



PACKAGING

Proper packing is essential to maintain the freshness of leafy vegetable. Packaging should be designed to prevent premature deterioration in product quality, in addition to serving as a handling unit. Use clean, smooth and ventilated containers for packaging. This is a very important factor in cutting down losses in these crops during harvesting, transportation, marketing and storage. Use containers that are appropriate for the crop.



TRANSPORTATION

Minimizing losses during transport necessitates special attention to vehicles, equipment, infrastructure, and handling. Load and unload transport vehicles carefully. Use clean, well-ventilated vehicle covered at the top for transportation. Transport crops during the cool part of the day by driving carefully over smooth roads to minimize damage to crop. Fresh produce must not be watered prior to loading, as this will lead to decay, rotting, and extensive losses. Major



causes of losses are improper handling during loading and unloading.

STORAGE

Only crops with high initial quality can be stored successfully; it is therefore essential to ensure that only crops of the highest quality (mature, undamaged) are stored. Shelf life can be extended by maintaining a commodity at its optimal temperature, relative humidity and environmental conditions.



PROCESSING

Processing is an important value-added activity that stabilizes and diversifies food supplies and creates employment and income opportunities. It can minimize the high perishability problem of leafy vegetables. Processed products are also more stable, have improved digestibility, and permit a better diet diversity, giving consumers access to a wider choice of products and a wider range of vitamins and minerals. Few processing technologies are listed: Drying, salting, fermenting, and pickling.

Conclusion

Post-harvest loss of vegetables can be considerably minimized and their storage life can be greatly increased by careful manipulation of these factors. The loss can be minimized by adopting necessary cultural operations, careful handling and packaging. The use of appropriate chemicals at pre and post-harvest stage, may extend the availability of vegetables over a long period by protecting them from microbial as well as environmental damage. Therefore, steps as already mentioned should be adopted, according to the suitability, and post-harvest loss of vegetables should be kept at minimum.



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“PURPLE CORN” – NUTRITIONAL SUPER FOOD OF THE NATURE

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Introduction

In the world of nutrition, color often signifies the presence of certain beneficial compounds. From the vibrant orange of carrots indicating a wealth of beta-carotene to the deep green of spinach hinting at its rich iron content, nature has a way of signaling the nutritional treasures within its bounty. One such treasure is the anthocyanin, a type of flavonoid that gives many fruits and vegetables their deep red, purple, or blue hues. Purple corn (*Zea mays* L.), a grain with one of the deepest shades in the plant kingdom, has caught the attention of the food industry as it could serve as a source for alternatives to synthetic colorants. Purple corn is rich in various health-promoting compounds, mainly anthocyanins and their malonylated forms. Also being rich in phenolic compounds with potential health-promoting properties, purple corn is becoming a rising star in the novel ingredients market.

Key words: Purple corn, Anthocyanins, Phenolic compounds, Super food

Introduction

The functional value of foods and beverages is of prime importance for consumers to balance their nutritional requirements and to reduce the risk of chronic diseases. Color diversity of plant-based products such as fruits, vegetables and fresh kernel foods including corn cultivars are abundant sources of different phytochemicals such as anthocyanins, carotenoids and conjugated polyphenols with enormous bioactivity and nutraceutical benefits. The functional components in fresh foods or beverages such as vitamins, minerals, antioxidants, dietary fiber,

phytosterols and essential fatty acids play a vital role in regulating normal biological activity in the human body.



Purple corn is quickly emerging as nature's new super food, boosting twice the number of antioxidants found in blueberries and pomegranate. In recent years, purple corn consumption has increased due to its high content of phenolic compounds, which act as powerful antioxidant, anti-inflammatory, antidiabetic, and anticancer agents. Anthocyanins, the vibrant pigments with their potent antioxidant properties gives purple corn its distinctive color which are associated with a range of health benefits. Due to the high content of functional pigments in by-products such as kernel, cob, and silk, it is urgent to improve the utilization of purple corn. Moreover, if more by-products of purple corn are developed, not just anthocyanins, purple corn may generate additional value in the future.

Historical Significance

Purple corn dates back to the time of the Incan Empire in 3000-2500 BC and scientifically classified as *Zea mays L.*, It originated in the mid-altitude region of central Peru then spread to the Peruvian coast and eventually to the high altitude Andean regions. In modern history, purple corn has been widely grown and harvested in the Andean region of South America—primarily Peru, Ecuador, Bolivia and Argentina. In Andean societies, purple corn serves not just as a dietary cornerstone but also as a potent emblem of cultural heritage. Purple corn was a popular food staple in ancient civilizations, including the Mayans, Incas and Aztecs. During the event of Inti Raymi, the Festival of the Sun, offerings of purple corn are presented to the gods as a gesture of gratitude for the harvests. In Andean cosmology, purple corn holds a significant position, symbolizing fertility, abundance, and a link to the divine.

Archaeological evidence suggest that all purple maize landraces in Peru originated from the ancient race called ‘Kculli’, or ‘Kulli sara’, which has been cultivated in Peru since prehispanic times. Currently, there are six widely used landraces of purple maize (Morado de Cusco, Morado Canteño, Morado de Caraz, Morado Arequipeño, Negro de Junín, and Huancavelicano) and five improved cultivars (‘INIA-615 Negro Canaán’, ‘INIA-601’, ‘PM-581’, ‘PM-582’, and ‘UNC-47’). In Peru, this pigmented corn is responsible for one third of the corn exports and is used as a coloring for typical beverages and desserts, such as “chicha morada” and “mazamorra morada,” respectively.

Health and Nutrition

Purple corn, is an excellent natural colorant, botanically identical to regular table corn, but appears deep purple color due to its high phenolic content and anthocyanins. The gluten-free flour of the purple corn gives bread, cakes, pastries and drinks an interesting purple color. This natural colorant is highly versatile, stable under various pH conditions, and compatible with a wide range of products, from beverages and yogurt to baked goods and snack bars. Its combination of vibrant color, health benefits, and natural origin makes purple corn a valuable choice for dietary diversification.



Nutritionally and compositionally, purple corn is similar to the more commonly consumed yellow corn as being rich in starch (61% to 78% dry basis), nonstarch polysaccharides (about 10% db), proteins (6% to 12% db), lipids (3% to 6% db), minerals, and vitamins. However, it is the presence of anthocyanins and other phenolic compounds that differentiate purple corn from other conventional corn varieties and make it stand out as a health promoting food. Its purple color is due to the presence of cyanidin-3-glucoside, an anthocyanin that is

located on the pericarp of the grain. The anthocyanin content of purple corn cob accounts for 30–47% of the total phenolic content.

Various phenolic phytochemicals have been characterized in purple corn, including anthocyanins, cyanidin-3-glucoside, pelargonidin-3-glucoside and peonidin-3-glucoside, cyanidin-3-(6''-malonyl glucoside), pelargonidin-3-(6''-malonyl glucoside), peonidin-3-(6''-malonyl glucoside), cyanidin-3-(6''-ethylmalonyl glucoside), pelargonidin-3-(6''-ethylmalonyl glucoside) and peonidin-3-(6''-ethylmalonyl glucoside). Phenolic acids such as p-coumaric acid, vanillic acid, protocatechuic acid, ferulic acid, p-hydroxybenzoic acid, p-hydroxyphenyl acetic acid, syringic acid, and caffeic acid have been found. Flavonoids such as derivatives of hesperitin, quercetin and kaempferol have also been reported in hydrolysates of the aleurone tissue of corn.

Recent research has shown that dietary consumption of anthocyanins was associated with a 15% reduction in the risk of type 2 diabetes. Additionally, purple corn can potentially reduce the risk of heart disease-most likely due to decreased coagulation of platelets and increased circulation of HDL cholesterol and can prevent long term kidney damage in people with type 2 diabetes by protecting renal cells. Diabetes is often associated with ophthalmology complications, so these antioxidants help increase visual acuity and improve night vision. Purple corn also aids in regeneration of connective tissue and collagen formation for healthy skin, which is important for diabetes management.

Understanding the Health Benefits of Anthocyanins

Antioxidant Properties of Anthocyanins:

As antioxidants, anthocyanins help neutralize harmful free radicals in the body. Free radicals are unstable molecules that can contribute to oxidative stress, which is linked to chronic diseases such as cardiovascular disease, cancer, and neurodegenerative disorders. By neutralizing free radicals, anthocyanins in purple corn help reduce oxidative stress and support overall cellular health.

Role of Anthocyanins in Promoting Heart Health:

Anthocyanins are believed to support heart health. They are known to help maintain healthy blood pressure levels and improve the overall function of blood vessels. Anthocyanins may help prevent the oxidation of LDL cholesterol (often referred to as “bad” cholesterol) and inhibit the formation of blood clots.

Anthocyanins and Their Potential Role in Weight Management:

Anthocyanins help to regulate metabolic activities and could potentially aid in maintaining a healthy weight.

Anthocyanins and Eye Health

Anthocyanins are also beneficial for eye health. They help support the health of the retina and improve night vision. They may help protect against age-related macular degeneration (AMD), a leading cause of vision loss in older adults. The antioxidant and anti-inflammatory properties of anthocyanins can help support the health of the retina and reduce the risk of AMD development.

Cognitive Function

Some studies have suggested a potential link between anthocyanin consumption and improved cognitive function. Anthocyanins may help protect brain cells from oxidative stress, reduce neuroinflammation, enhance memory and cognitive performance.

Skin Health

Some phytonutrients have been shown to benefit skin health by protecting against UV damage, reducing oxidative stress, and promoting collagen synthesis. They can contribute to a healthy complexion, skin elasticity, and may have anti-aging effects.

Anti-Inflammatory Properties

Anthocyanins have been shown to possess anti-inflammatory effects. Chronic inflammation is associated with various diseases, including heart disease, diabetes, and certain cancers. By reducing inflammation, anthocyanins in purple corn may contribute to the prevention or management of inflammatory conditions.

Harnessing the health benefits of purple corn's anthocyanins

It can be achieved in various ways as given below

Purple Corn Extract

This is a concentrated form of purple corn that packs a powerful punch of anthocyanins. It's used as supplements and can be added to smoothies, juices, or even water for a quick and easy health boost. Traditionally used in South America to make a sweet beverage known as "chicha morada."

Whole Purple Corn

Whole purple corn can be prepared similarly to sweet corn. It can be boiled, grilled, or

roasted and served as a side dish, or incorporated into salads, soups, and stews for a pop of color and a boost of nutrients.

Purple Corn Flour

This flour can be used as an alternative to regular flour in baking and cooking. It's perfect for making bread, pancakes, muffins, and other baked goods, and can also be used as a thickening agent in soups and sauces.

Purple Corn meal

Ideal for making polenta, cornbread, or other corn-based dishes, purple cornmeal can also be used as a breading for fish or chicken, adding a unique twist to meals.

Purple Corn Chips

Add a touch of excitement to chips, popcorn, and even healthier snack alternatives.

Other uses Beyond Food

Natural Dye

Purple corn's vibrant color can be used as a natural dye for textiles and other applications.

Cosmetics

Purple corn is also used in Cosmetics which Provides natural pigment in lip balms and eye shadows

Conclusion

Purple corn, with its high anthocyanin content, offers a unique and delicious way to incorporate the beneficial compounds into our diet. In the last decade, the utilization of purple corn has increased steadily due to the presence of health-promoting anthocyanin compounds. In particular, purple corn extracts exhibited significant antioxidant, anticancer, anti-diabetic, anti-obesity and anti-inflammatory potentials. From their antioxidant properties to their potential role in heart health, weight management and eye health, anthocyanins are truly a nutritional powerhouse. Anthocyanins, the multifunctional active substances in purple corn, may be of interest to various industries such as dietary supplements, food additives, and cosmetics. Advances in functional genomic analysis of anthocyanin biosynthetic pathways using recombinant DNA technology and the combination of plant metabolic engineering with biotechnological tools will be a promising strategy to increase anthocyanin production.



Furthermore, mechanistic, bioavailability and clinical studies are warranted to confirm these beneficial effects to enhance the nutritional and health benefits of purple corn.

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SOIL AND WATER CONSERVATION: A PATHWAY TO CLIMATE -RESILIENT AGRICULTURE

Article ID: AG-VO5-I06-88**R. Rebecca¹, *S.U. Vikraman², K. Suriya³**

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Abstract

Climate change has intensified extreme weather events, increasing rainfall-runoff erosivity and accelerating soil erosion and sediment yield. This leads to the loss of fertile topsoil, organic carbon, and nutrients, reducing soil-water retention and threatening agricultural productivity. To combat these impacts, sustainable soil and water conservation practices are essential for climate-resilient farming. Techniques such as proper tillage, compartmental bunding, and furrow systems help control runoff and prevent soil loss. Practices like mulching, cover cropping, vegetative barriers, and conservation agriculture improve soil structure, reduce erosion, and enhance crop yields. Efficient water management through drip irrigation and rainwater harvesting is crucial in drought-prone regions to optimize water use. Organic methods, including biochar application and agroforestry, promote soil carbon sequestration and ecological stability. Climate-smart agriculture featuring precision farming and resilient crop varieties offers adaptive solutions to mitigate climate effects. However, widespread adoption faces challenges such as high implementation costs, limited farmer awareness, and policy constraints. Bridging these gaps requires integrating traditional knowledge with modern science and strengthening support for small-scale farmers. Collaborative efforts among governments, researchers, and communities are vital to promote sustainable practices and ensure the long-term resilience of agricultural systems in the face of a changing climate.

Keywords: Soil; water; conservation; Climate change; Agriculture

Introduction

Conservation of soil and water resources is crucial for ensuring the sustainability of both agriculture and the environment. One of the major challenges to soil health is soil erosion. This erosion significant deteriorative process that leads to the degradation of fertile topsoil, reducing land productivity and contributing to environmental issues such as sedimentation and water pollution (Kizito et al., 2022). To safeguard these vital resources, it is essential to implement effective soil erosion control measures. These may include afforestation, contour ploughing, terracing, cover cropping, and the construction of check dams, all of which help to stabilize the soil, reduce runoff, and maintain the integrity of the land for future agricultural use (Figure 1).



Figure 1. Soil and water conservation

Purpose of Soil and Water Conservation Measures

Soil and water conservation measures are predominantly applied for the following purposes:

- ☐ To control runoff and thus prevent loss of soil by soil erosion, to reduce soil compaction.
- ☐ To maintain or to improve soil fertility.
- ☐ To conserve or drain water.
- ☐ To harvest (excess) water.

Classification of Soil and Water Conservation Measures

- Physical measures (also termed mechanical or technical measures).

- Biological measures (also termed vegetative measures).
- Agronomic measures (sometimes called best management practices).

Physical measures

Increasing the time of concentration of runoff is a key strategy in soil and water conservation, as it allows more water to infiltrate into the soil rather than flowing away. This approach helps to divide long slopes into several shorter sections, thereby reducing both the volume and velocity of surface runoff. Slowing down runoff not only minimizes soil erosion but also enhances groundwater recharge.

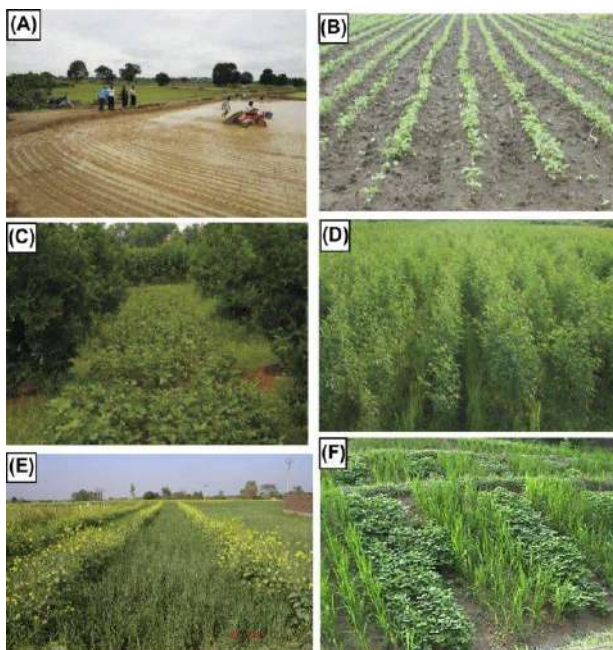


Figure 2. Recommended management practices: (A) Transplanting of rice with Paddy Transplanter; (B) Rainy season crop with ridge furrow system; (C) Custard apple (*Annona reticulata*)-based agri-horti system; (D) Ridge furrow planting of rice and pigeon pea; (E) Improved intercropping systems; (F) Intercropping of cereal and legume (Rao *et al.*, 2015).

Additionally, controlling the speed and flow of runoff helps protect land from damage caused by excessive water movement (Figure 2). To achieve these goals, various physical measures can be implemented, such as constructing check dams, contour ditches, and other structural interventions that are adaptable to most land management systems (Rao *et al.*, 2015).

Biological measures

A dense vegetation cover plays a vital role in preventing soil erosion and enhancing water conservation. It helps prevent splash erosion by shielding the soil surface from the direct impact

of raindrops. Vegetation also slows down the velocity of surface runoff, allowing more water to infiltrate the soil rather than being lost as runoff (Rao *et al.*, 2015).. The presence of plant roots and organic matter stabilizes soil aggregates, making the soil structure more resistant to erosion and further improving water infiltration (Figure 3.). Additionally, vegetation increases surface roughness, which helps trap soil particles and reduce runoff, thereby promoting the accumulation of soil and enhancing overall soil health.

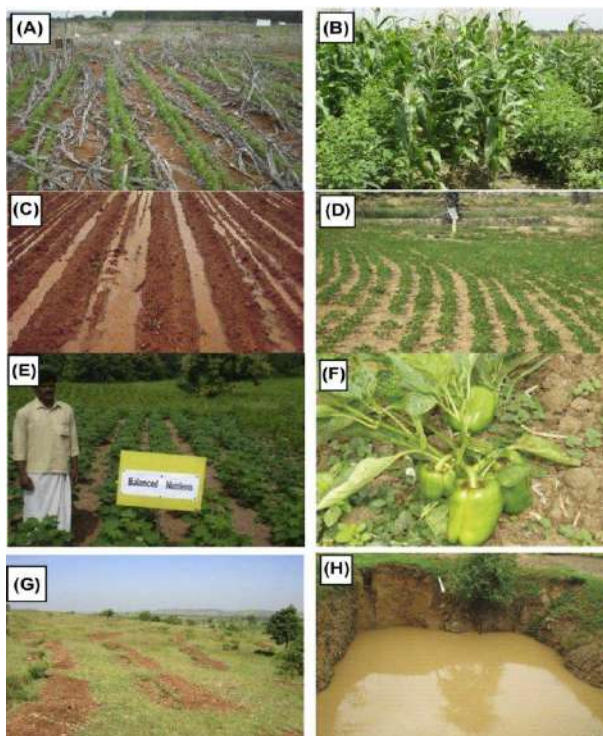


Figure 3. Recommended management practices: (A) Residue incorporation; (B) Legume intercrop; (C) Ridge and furrow; (D) Sowing across the slope; (E) Balanced nutrition; (F) Vermicompost use in vegetables; (G) Contour bunding; (H) Recharging open wells with runoff water from fields (Rao *et al.*, 2015).

Agronomic conservation measures

Reducing the impact of raindrops through interception by vegetation is an effective way to minimize soil erosion (Nithinkumar & Gairola). When plant leaves and canopy structures intercept rainfall, they lessen the force with which raindrops hit the soil surface, thereby preventing the dislodging of soil particles.

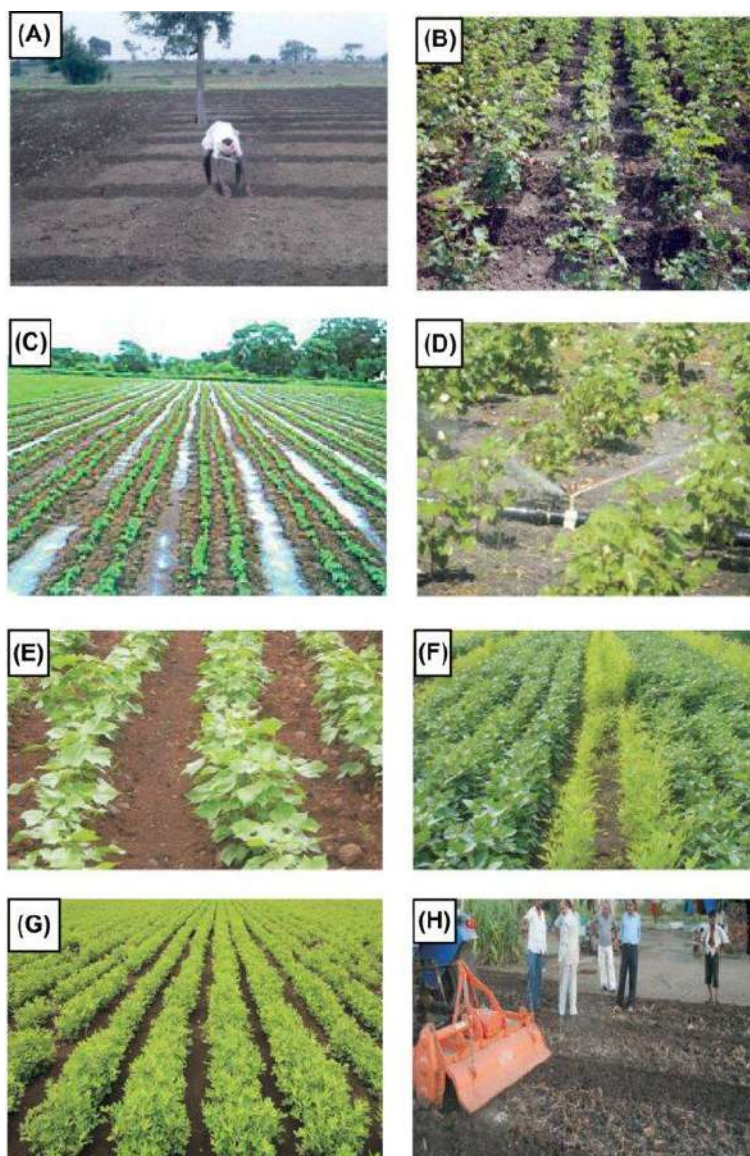


Figure 4. Recommended management practices: (A) Compartmental bunding; (B) Ridge and furrow; (C) Broad bed furrow; (D) Supplemental irrigation; (E) Furrow openings in cotton; (F) Ridge and furrow system in soybean and pigeon pea; (G) Improved variety of groundnut; (H) Incorporation of cotton stalks with rotavator (Rao *et al.*, 2015).

However, vegetation enhances the soil's ability to absorb water by increasing infiltration rates. This not only reduces surface runoff but also limits the amount of soil erosion, contributing to improved soil stability and better water conservation. Hence, these processes play a crucial role in maintaining soil health and supporting sustainable land use (Figure 4) (Rao *et al.*, 2015).

Climate Changes IMPACTS: RAINFED AGRICULTURE

Climate variability will erode the resources base, and affect ecosystem services:

- ☐ Recurrent droughts & severe floods.
- ☐ Droughts will decrease yields / productivity.
- ☐ Floods may damage crops and infrastructure (irrigation, road).
- ☐ Complicate farm operations and services.
- ☐ Fluctuations in farmers' income.
- ☐ Impact on national economy, with 90% probability (Figure 5) (Rao *et al.*, 2015). (Misra, Prasad, & Bhan, 2022).



Figure 5. Loss of top fertile soil layer through soil erosion in high intensity rains in low rainfall regions (A, B) and high rainfall hill regions (C, D) (Rao *et al.*, 2015).

IMPACTS: IRRIGATED AGRICULTURE

- ☐ Glacier melt of water towers causes temporary increase/ decrease in water reserves.
- ☐ Changes in groundwater recharge.
- ☐ Changes in timing and magnitude of river flows (irrigation schemes tapping directly from river, and storage requirements) (Figure 6).
- ☐ Temperature effects on water productivity and unproductive evaporation.
- ☐ CO₂, fertilization and irrigation productivity (Kumar & Pandey, 2024).



Figure 6. Impact of irrigated agriculture

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SUSTAINABLE SOLUTION FOR A GREENER FUTURE

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Introduction

Today, fossil fuels are among the most widely used energy sources in the world, powering transportation, electricity generation, heating, and industrial processes. Despite their economic importance and energy density, fossil fuels are non-renewable resources, meaning they cannot be replenished on a human timescale. But their extraction, processing, and use come with significant environmental, health, and societal impacts. Burning fossil fuels releases harmful pollutants such as sulfur dioxide (SO₂), nitrogen oxides (NO_x), and particulate matter, leading to smog and acid rain. Fossil fuels are the largest source of carbon dioxide (CO₂) emissions, a greenhouse gas that contributes to global warming and climate instability. Organic waste, as the main constituent of solid biomass, has a high potential for biochar generation. Biomass waste materials appropriate for biochar production include crop residues from agriculture, forestry, municipal solid waste, food and animal manures, etc. Biochar is a type of charcoal that is produced by heating organic material (such as wood, crop residues, or manure) in a low-oxygen environment a process called pyrolysis. It is used primarily as a soil amendment to improve soil health, sequester carbon, and increase agricultural productivity. Biochar derived from biomass is an exceptionally rich wellspring of carbon produced from biomass utilizing thermal combustion.

How the Biochar is produced

Pyrolysis is the key process used to produce biochar. It involves the thermal decomposition of organic materials (biomass) in the absence or near-absence of oxygen. Unlike combustion, which produces energy and CO₂, pyrolysis breaks down biomass into biochar, bio-oil, and syngas, with minimal oxygen to prevent burning. This process is an alternate strategy for converting the waste biomass into value-added products like biochar, syngas and bio-oil. The

biochar yield during the pyrolysis process depends on the type and nature of biomass used. Temperature is the main operating process condition that decides the product efficiency. Generally, the yield of biochar decreases and production of syngas increases when the temperature is increased during the pyrolysis process. Pyrolysis can be classified as a fast and slow pyrolysis process depending on the heating rate, temperature, residence time and pressure.

Impact of biochar on environment

Biochar has a variety of positive environmental impacts, making it a powerful tool in sustainable agriculture, climate change mitigation, and ecological restoration. Carbon sequestration: Biochar is highly stable and carbon-rich, allowing it to store carbon in soils for hundreds to thousands of years. Reduces atmospheric CO₂, helping to mitigate climate change. When biochar is utilized for treating wastewater, the carbon content of water increases due to the release of carbon by biochar. Similarly, when biochar acts as a catalyst, the stability gradually decreases on reusing biochar several times. Though biochar is utilized for various purposes, its influence on the environment must be analysed properly to avoid its negative impacts. The biochar produced from sludge containing heavy metals may percolate during the treatment process thus causing heavy metal contamination. Similarly, when biochar acts as a catalyst, the stability gradually decreases on reusing biochar several times. The instability of biochar may be due to structural damage also. Hence stability of biochar plays an important role in environmental concern.

Biochar can help reduce N₂O emissions from agricultural soils by increasing soil pH, reducing soil compaction, and enhancing soil microbial activity. Biochar application significantly reduced N₂O emissions from sandy-loam soil. The reductions were as high as 50% which was consistent across a range of biochar application rates and soil-moisture conditions. According to a meta-analysis study, biochar application was able to reduce N₂O emissions by an average of 26%. The reductions were more pronounced in soils with high levels of available nitrogen. Biochar application can affect soil N₂O emissions in different ways, depending on the edaphic conditions. Biochar can increase nitrification, leading to enhanced N₂O emissions when soil ammonium concentrations are high due to fertilizer application. Biochar has been demonstrated to effectively reduce CH₄ emissions from various sources such as livestock manure, rice fields, and landfills. The mechanism behind this reduction is believed to be the adsorption of CH₄ onto the biochar surface, which subsequently undergoes microbial oxidation.

One previous study found that spruce-wood biochar, applied at a 10 t ha⁻¹ for 7 years, dramatically reduced CH₄ gas emissions by up to 43%. A meta-analysis comprising 43 papers has also revealed that the application of biochar has resulted in a significant reduction of CH₄ emissions by an average of 37.9% in East Asian rice fields.

Recent biochar applications focus on utilizing biochar for removing organic pollutants from soil and water. Biochar when applied to soil, adsorbs organic pollutants present in the soil. Few organic contaminants include agricultural chemicals such as insecticides, herbicides, pesticides, fungicides like atrazine, simazine, carbofuran, etc., industrial chemicals such as PAHs (polycyclic aromatic hydrocarbon) including phenanthrene, catechol, pyrene, naphthalene, anthracene, etc., antibiotics and drugs like acetaminophen, tetracycline, ibuprofen, sulfamethazine, tylosine, etc., cationic dyes such as methylene blue, rhodamine, methylene violet, etc., and volatile organic compounds such as butanol, benzene, furan, trichloroethylene, etc.

It's Role on enhancing soil health

Applying biochar to soil can create a favorable environment for the growth of plants and uptake of nutrients by improving both the physiochemical and biological properties of the soil, such as porosity, water infiltration, WHC, aggregate stability, bulk density, soil hardness, pH, cation exchange capacity, and nutrient cycling. Biochar has been found to increase soil porosity by creating channels and spaces in the soil for air and water, promoting nutrient uptake and overall crop productivity. Porous soil can absorb and retain pollutants while sequestering CO₂ from the atmosphere. Biochar can improve soil WHC by increasing the porosity of the soil, providing a surface for water to adhere. The larger surface area of biochar allows it to hold more water per unit volume of soil while the porous structure of biochar helps improve water retention.

The pores in biochar provide a network of water-filled channels through which water can move more easily. By reducing water runoff and erosion, biochar is particularly beneficial in regions with limited water resources or extended dry periods and limited irrigation. The amount of water that biochar can hold depends on the type of biochar, pyrolysis conditions, and soil type. In general, biochar can increase the WHC of soil by 10%30%. Likewise, the addition of biochar to sandy soil reportedly increased the WHC by 20% . while adding it to clay soil increased the WHC by 30%. Nutrient leaching is a significant issue in agriculture, leading to soil degradation

and reduced crop yields. Biochar has been observed to help mitigate nutrient leaching by improving soil structure and increasing nutrient retention. The high CEC of biochar allows it to bind to nutrients and prevent them from being leached away by water. As biochar can also improve soil structure, the soil becomes more porous, which allows water to drain more slowly.

This gives the plants more time to absorb nutrients before they are leached away. The incorporation of biochar into calcareous soil was observed to facilitate the decomposition of calcium carbonate and release nutrients and increase their availability to plants. Soil pH is an important factor controlling the growth and health of plants. Acidic soils can have a number of negative effects on plant growth, such as reduced nutrient availability, increased susceptibility to pests and diseases, and stunted growth. Biochar can neutralize acidity and/or raise the pH of soil by releasing alkaline compounds such as potassium carbonate and calcium carbonate. In addition, biochar can help soil efficiently buffer changes in pH. However, biochar can also have a negative impact on soil pH if it is applied to alkaline soils. The effect of biochar on soil pH is dependent on the type of feedstock, pyrolysis conditions, and soil type.

My review

Biochar stands out as a promising solution at the intersection of agriculture, environmental sustainability, and climate change mitigation. Derived from organic waste through pyrolysis, it offers a practical way to improve soil health, enhance crop productivity, and sequester carbon for the long term. When used responsibly, biochar can reduce greenhouse gas emissions, manage organic waste effectively, and restore degraded lands. As the world looks for sustainable strategies to address global environmental challenges, biochar represents a simple yet powerful tool with the potential to support both ecological balance and food security. Embracing biochar is not just a step toward better farming-it's a step toward a more sustainable future.

GROW YOUR OWN SUPERFOODS: THE POWER-PACKED PROMISE OF MICROGREENS IN INDIA

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Introduction

Over the past ten years, society around the world has been more interested in consuming fresh, nutritious, and useful foods like sprouted seeds and microgreens, particularly during and after the COVID-19 epidemic. Along with offering beneficial nutritional contents, they also satisfy consumers' need for taste and novelty. Additionally, because they require little production and achieve their maximum consumption in a comparatively short amount of time, they are a particularly appealing commodity for manufacturers.



In the world of nutrition and sustainable living, *small is the new powerful*. Meet **microgreens**—the tender, young shoots of vegetables and herbs that pack more punch than their fully grown counterparts. These miniature greens are fast becoming a staple in kitchens, restaurants, and health-conscious households worldwide.

Microgreens: The Tiny Greens with a Giant Impact

In a world turning toward healthier eating and sustainable living, **microgreens** have emerged as the green heroes of modern nutrition. These delicate, young shoots—harvested just after the first true leaves appear—are not just a culinary trend but a **nutritional revolution**.



Often called “*living superfoods*”, microgreens are grown from the seeds of vegetables, herbs, or grains and harvested within 7 to 14 days. Despite their tiny size, they pack a concentrated dose of vitamins, antioxidants, and minerals, sometimes up to 40 times more than their mature plant counterparts.

“Don’t judge them by their size. Microgreens are a powerhouse of nutrition in just a handful.”

— *Dr. Gene Lester, USDA Researcher on Microgreens*

From urban balconies in Mumbai to rooftop farms in New York, microgreens are being cultivated for personal use, gourmet dishes, and commercial farming. Their short growing cycle, minimal resource requirement, and high nutritional value make them ideal for today's fast-paced, health-conscious lifestyle. **"The future of food may just be miniature."**

— *Chef Alice Waters, Farm-to-Table Pioneer*

What are Microgreens?

Microgreens are young vegetable greens harvested just after the first true leaves have developed. They are typically 1–3 inches tall and are grown from the seeds of herbs, vegetables, or grains. Common varieties include Radish, Broccoli, Mustard, Basil, Sunflower, Pea shoots, Coriander. They are often confused with sprouts, but unlike sprouts, microgreens are grown in soil or a growing medium and require sunlight.

Comparison of Microgreens, Sprouts, Baby Greens, and Mature Plants

Feature / Type	Sprouts	Microgreens	Baby Greens	Mature Plants
Growth Medium	Water (no soil)	Soil or cocopeat	Soil or hydroponic systems	Soil or hydroponic systems
Light Requirement	No light (dark environment)	Requires light	Requires light	Requires full sunlight
Harvest Time	2–5 days after germination	7–14 days after germination	15–30 days	30–90+ days depending on plant
Plant Parts Eaten	Entire sprout (seed, root, shoot)	Stem and first true leaves	Leaves (small but mature)	Leaves, stems, roots, fruits, seeds



Feature / Type	Sprouts	Microgreens	Baby Greens	Mature Plants
Nutrient Density	Moderate	Very high (up to 40x mature plant)	High	Moderate to high (varies by plant)
Taste	Mild to tangy	Intense, concentrated flavor	Mild but more developed	Fully developed flavor
Shelf Life	1–2 days	5–7 days (refrigerated)	5–10 days	7–14+ days (varies by part)
Food Safety Risk	Higher (due to humid growth)	Low to moderate	Low	Lowest (if properly handled)
Common Uses	Smoothies, sandwiches	Salads, garnishes, health dishes	Salads, wraps, sautés	Regular cooking and raw consumption

Nutritional Powerhouse

Despite their tiny size, microgreens are a nutritional powerhouse. According to a USDA study, many microgreens contain 4 to 40 times more nutrients than their mature counterparts. These vibrant greens are especially rich in Vitamins C, E, and K, Beta-carotene, Lutein, Polyphenols, Minerals like calcium, magnesium, iron.

Certain microgreen types offer distinct nutritional advantages compared to their mature counterparts: **Red Cabbage** microgreens are notably high in Vitamin C and Vitamin E, while **Cilantro** microgreens are rich in lutein and beta-carotene. **Radish** microgreens are abundant in antioxidants and polyphenols, and **Pea Shoots** serve as an excellent source of folate, fiber, and protein.

Microgreens: Why they're trending now?

The demand for microgreens is currently booming due to several key factors: a **growing interest in functional foods**, the **rise of urban farming and vertical gardening**, increased **awareness about nutrition and immunity**, and a strong **preference for pesticide-free fresh produce**.

Reason	Why it matters today
High Nutrition	Supports health and disease prevention
Quick & Easy to Grow	Perfect for urban homes and beginners

Reason	Why it matters today
Sustainable Agriculture	Low-resource, eco-friendly cultivation
Culinary Versatility	Enhances food quality and presentation
Market Demand	Growing consumer and chef interest
Local Food Security	Promotes urban farming and community resilience

In India cities like Bengaluru, Delhi, Mumbai, and Hyderabad have seen a surge in rooftop farms and startups growing microgreens for gourmet restaurants and health stores. Even small farmers are now adopting this high-margin crop due to its short growing cycle (7–14 days).

How to Grow Microgreens at Home?

Growing microgreens is easy, low-cost, and requires little space—perfect for urban homes.

➤ Materials Needed:

To start growing microgreens, you will need several materials: **shallow trays or containers, organic potting mix or cocopeat, non-treated (preferably organic) seeds, a spray bottle, and either natural light or a grow light.**

➤ Steps to Grow:

1. Fill tray with potting mix.
2. Sprinkle seeds densely and press gently.
3. Mist water evenly using a spray bottle.
4. Cover for 2-3 days until seeds germinate.
5. Expose to light and water daily.
6. Harvest in 7–10 days by cutting just above the soil.



Key conditions for microgreens

Factor	Requirement / Best Practice
1.Growing Medium	Use sterile, well-draining media like cocopeat, organic potting soil, or grow mats (e.g., jute, hemp). Avoid heavy or compacted soil.
2.Containers/Trays	Use shallow trays (1–2 inches deep) with drainage holes. Food-grade plastic, bamboo, or biodegradable trays are commonly used.

Factor	Requirement / Best Practice
3. Seeds	Use untreated, organic, non-GMO seeds. Choose seeds specifically labeled for microgreens for better success and safety.
4. Light	Provide bright indirect sunlight (4–6 hours) or use LED/grow lights. Avoid direct, harsh sunlight to prevent drying or burning.
5. Temperature	Optimal range is 18°C–24°C (65°F–75°F). Avoid extremes—too cold slows growth, too hot causes stress.
6. Humidity	Maintain moderate humidity (40%–60%). High humidity encourages fungal growth, so ensure airflow.
7. Watering	Water gently using a spray bottle or misting can. Keep the growing medium moist but not soggy. Bottom watering is also effective.
8. Air Circulation	Ensure good ventilation to prevent mold and fungal diseases. Use small fans in indoor setups if needed.
9. Hygiene	Sterilize trays and tools before reuse. Use clean water and wash hands or wear gloves to prevent contamination.
10. Harvesting Time	Harvest when first true leaves appear, usually in 7–14 days, by cutting above the soil line with clean scissors.

How to use Microgreens?

Microgreens are incredibly versatile and can be used to elevate the flavor, color, and nutrition of various dishes: **sprinkle them on salads, sandwiches, or soups; blend them into smoothies and juices; use them as a garnish on omelets, pasta, or pizzas; or add them to wraps, sushi, and rice bowls.**



Cultivating Success: Diverse Microgreen Ventures

- A home gardener in Pune grows mustard and fenugreek microgreens on her balcony, harvesting fresh greens every week for salads and smoothies.
- A startup in Delhi supplies radish and broccoli microgreens to five-star hotels using hydroponic systems.

Your next green step

Ready to elevate your plate and perhaps even your lifestyle? The world of microgreens is waiting, and it's surprisingly easy to enter. Imagine the vibrant colours, the fresh aromas, and the incredible nutritional punch you could be adding to your daily meals, all grown by your own hands. Starting your microgreen journey requires minimal space and effort, making it a perfect fit for any Indian home. Pick up a packet of your favourite seeds – perhaps some peppery radish, aromatic coriander, or earthy fenugreek – and a small tray. In just days, you could be harvesting your own "green gold," adding a powerful, pesticide-free boost to your family's diet. It's a small step that yields big returns for your health, your kitchen, and potentially, even your entrepreneurial spirit. Let's start sprouting!

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SCIENTIFIC CULTIVATION OF SPONGE GOURD: A COMPREHENSIVE GUIDE

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Abstract

Sponge gourd, also known as *Luffa*, is a tropical vegetable belonging to the *Cucurbitaceae* family. Known for its high nutritional value and potential as a natural sponge when dried, the cultivation of sponge gourd has gained increasing interest in both agricultural and commercial sectors. Its ability to grow in a wide range of environmental conditions, along with its numerous applications in the food, medicinal, and industrial sectors, has made it an important crop in various regions across the world. This article aims to explore the scientific cultivation of sponge gourd, providing an in-depth understanding of the best practices, techniques, and innovations that contribute to successful cultivation, improved yield, and quality production.

Keywords: Sponge gourd, scientific cultivation, Crop management, Organic farming, Drip irrigation, Pest and disease control, Sustainable agriculture, Post-harvest handling, integrated pest management (IPM)

Introduction

Sponge gourd, scientifically known as *Luffa cylindrica*, is a fast-growing, annual climbing plant native to tropical and subtropical regions. While it is typically grown for its edible tender fruit in many regions, the mature fruit is primarily valued for its fibrous interior, which is used to make natural sponges for cleaning purposes. The crop is relatively easy to cultivate and can be grown on a small scale for household use or on a large scale for commercial purposes.

Sponge gourd thrives in warm, humid climates, requiring full sunlight and well-drained soil to achieve optimal growth.

Understanding its cultivation requirements, pest management strategies, and post-harvest processing is essential for maximizing productivity and quality.



Figure: Sponge gourd plant

BOTANICAL DESCRIPTION

Sponge gourd is a fast-growing, herbaceous vine that can grow up to 6-8 meters in length. The plant has large, lobed leaves and tends to develop dense vines. The flowers of the sponge gourd are unisexual and appear yellow. Male flowers are usually borne on long stems, while female flowers appear close to the base of the plant. The fruit of the sponge gourd is initially green and tender, but as it matures, it turns yellow and eventually brown, developing a tough fibrous interior. The mature, dried fruit is used as a natural sponge.

VARIETIES OF SPONGE GOURD

There are two main types of sponge gourd:

1. Edible Sponge Gourd (Tender Gourd)

This variety is grown primarily for its immature, tender fruit, which is used in culinary dishes across the world. It is often stir-fried, boiled, or used in soups. The tender fruit is long, cylindrical, and green in color.

2. Fibrous Sponge Gourd (Mature Gourd)

This type is cultivated primarily for its mature fruit, which is dried and processed into natural sponges. These gourds are harvested when fully ripe, allowing the seeds to mature and the fibrous interior to develop fully.

CLIMATIC REQUIREMENT

Sponge gourd requires a warm tropical to subtropical climate with temperatures ranging from 25°C to 35°C for optimal growth. It thrives in areas with high humidity and plenty of sunshine. Frost is detrimental to sponge gourd, as it can stunt growth or cause damage to the

vines and fruit. In regions with harsh winters, sponge gourd can be cultivated in green houses or under polyhouses to simulate the optimal growing conditions.

SOIL REQUIREMENT

Sponge gourd grows best in well-drained, loamy or sandy soil with a pH range of 6.0 to 7.5. The soil should be rich in organic matter, which can be enhanced through the addition of well-decomposed compost or farmyard manure. Before planting, it is essential to prepare the soil properly by Ploughing and tilling to a depth of about 25-30 cm. incorporating organic material into the soil improves water retention and nutrient content, which in turn enhances plant growth.

PROPAGATION TECHNIQUES

1. Seed Selection

The quality of seeds is critical for successful sponge gourd cultivation. Use certified seeds from reputable sources to avoid the introduction of diseases and pests. Good-quality seeds ensure strong germination rates and healthy plant growth. Select seeds that are disease-resistant and well-suited to your local climate and soil conditions.

2. Seed Treatment

Before sowing, it is recommended to treat the seeds with fungicides to prevent seed-borne diseases. Soaking the seeds in water for 12-24 hours before sowing can also improve germination rates by softening the seed coat.

3. Sowing

Sponge gourd can be propagated by direct seeding or through nursery transplanting. However, direct seeding is the most commonly used method. In regions with warm climates, seeds can be sown directly in the field during the monsoon season or when temperatures stabilize above 25°C. Seeds can be sown by maintaining a distance of 2.0-2.5 meters between rows and 50-75 cm between seeds within the row. In cooler climates, seeds can be germinated in trays or pots and then transplanted to the field once the seedlings are 20-30 cm tall.

CROP MANAGEMENT PRACTICES

a) Irrigation

Sponge gourd requires consistent moisture for healthy growth, especially during the flowering and fruiting stages. Regular irrigation is essential during dry periods, but water logging should be avoided as it can lead to root rot and other diseases.

Drip irrigation is highly recommended for sponge gourd cultivation as it delivers water

directly to the root zone, conserving water and minimizing the risk of fungal diseases. In areas with abundant rainfall, natural rainfall may suffice, but supplemental irrigation may still be required during dry spells.

b) Fertilization

The nutrient requirements of sponge gourd are high, particularly during the vegetative and fruiting stages. A balanced fertilization program is essential to ensure healthy growth and high yields. In case of Organic Fertilizers, apply well-decomposed compost or farmyard manure at the time of planting. This improves soil structure and enhances nutrient availability.

In case of Chemical Fertilizers, apply nitrogen (N), phosphorus (P), and potassium (K) fertilizers in a 2:1:2 ratios, based on soil test recommendations. Nitrogen encourages leaf and vine growth, while phosphorus aids in root and flower development. Potassium helps in fruit formation and overall plant health.

Fertilizer should be applied in split doses, with the first dose given at planting and subsequent doses during the vegetative growth phase and before fruiting.

c) Pruning

Regular pruning is essential for maintaining plant health and promoting higher yields. Prune the plant to remove any dead or diseased parts. Pinch off the tips of the vines to encourage branching, which results in more flowers and fruits. Also, prune to maintain proper plant spacing and allow for good air circulation, which reduces the risk of fungal infections.

d) Pollination

Sponge gourd is primarily pollinated by insects, particularly bees. However, in some cases, pollination can be insufficient, leading to poor fruit set. To ensure good pollination, consider planting bee-friendly plants nearby or introducing beehives to the farm. In regions where insect pollination is insufficient, manual pollination can be done by transferring pollen from male flowers to female flowers using a small brush or cotton swab.

PEST AND DISEASE MANAGEMENT

COMMON PESTS

Several pests can affect sponge gourd crops, including:

1. Aphids

Small, soft-bodied insects that suck sap from the plant, leading to stunted growth and the spread of viruses.

2. Whiteflies

These pests can damage plants by feeding on the leaves and transmitting viral diseases.

3. Fruit Flies

Fruit flies lay eggs on the fruit, and the larvae feed on the developing fruit, causing it to rot.

4. Caterpillars and Larvae

Various caterpillar species may attack the vines, leaves, or fruit.

Integrated Pest Management (IPM) practices, including biological controls, can help manage pests effectively without the excessive use of chemical pesticides.

COMMON DISEASES

Powdery Mildew

A fungal disease, that appears as a white, powdery substance on the leaves. Preventive fungicide treatments can control this disease.

Downy Mildew

A fungal infection, that causes yellowing and wilting of leaves. It is often controlled by spraying copper-based fungicides.

Root Rot

Caused by water logging or poor drainage, root rot can damage the plant's root system, leading to poor growth and eventual death of the plant.

Regularly inspect plants for signs of disease and apply appropriate fungicides or organic treatments as needed.

HARVESTING AND POST-HARVEST MANAGEMENT

Harvesting Edible Fruit

Sponge gourd fruit can be harvested when it reaches 20-30 cm in length and is still tender. The fruit is typically harvested by hand, cutting it carefully from the vine using sharp pruning shears or a knife. Harvesting should be done in the early morning to reduce stress on the plant.

Harvesting Mature Fruit

For sponge production, allow the fruit to mature fully on the vine until it turns yellow and starts to dry out. Once the fruit has dried, it can be harvested, and the seeds are extracted. The fibrous interior is cleaned and processed into sponges.

POST-HARVEST HANDLING

After harvesting, sponge gourd fruits should be handled with care to maintain their quality. Freshly harvested fruits should be stored in a cool, shaded area to prevent wilting and spoilage. For mature fruits intended for sponge production, the following steps are recommended:

Cleaning: Thoroughly clean the fruits to remove any dirt or debris.

Drying: Place the fruits in a well-ventilated area to allow them to dry completely. This process can take several weeks, depending on the environmental conditions.

Processing: Once dried, the outer skin can be peeled off to reveal the fibrous interior, which can be further processed into sponges or other products.

ECONOMIC IMPORTANCE

Sponge gourd cultivation offers multiple economic benefits:

Nutritional Value

The tender fruits are rich in vitamins A and C, making them a valuable addition to the diet.

Medicinal Uses

Various parts of the plant are used in traditional medicine to treat ailments such as diabetes and skin diseases.

Commercial Products

The mature, dried fruits are processed into natural sponges, which have applications in cleaning and personal care products.

CONCLUSION

Scientific cultivation of sponge gourd involves understanding and implementing best practices in soil preparation, planting, irrigation, pest and disease management, and post-harvest handling. By adhering to these practices, farmers can achieve high yields and quality produce, contributing to both their economic well-being and the availability of this versatile crop in the market.

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MULTIPURPOSE USE OF MULBERRY

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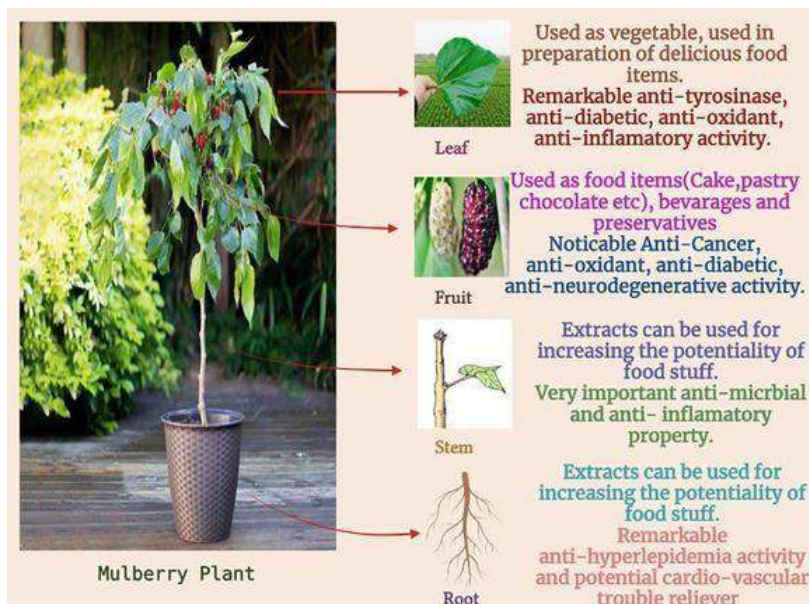
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Abstract

The mulberry plant (*Morus* spp.) is globally recognized as a highly versatile and economically valuable crop, primarily known for its pivotal role in the sericulture industry as the exclusive food source for the silkworm (*Bombyx mori*). However, beyond its indispensable importance in silk production, mulberry holds immense potential in various sectors due to its nutritional, medicinal, environmental, and industrial applications. Mulberry leaves are rich in protein, vitamins, and minerals, making them useful as livestock feed, particularly for cattle, sheep, and goats. Its fruits are consumed fresh or processed into jams, juices, wines, and health supplements, owing to their high content of antioxidants, anthocyanins, and dietary fiber. The plant also exhibits numerous medicinal properties; its leaves, bark, and roots are used in traditional medicine systems such as Ayurveda, Chinese medicine, and Unani for managing diabetes, reducing cholesterol, and improving liver health. Environmentally, mulberry plays a role in soil conservation, afforestation, and carbon sequestration due to its adaptability and fast growth. Additionally, extracts from various parts of the plant are utilized in cosmetics and nutraceutical industries for their anti-aging, anti-inflammatory, and antimicrobial effects. Thus, mulberry is not merely a sericulture plant but a multipurpose resource that contributes to agriculture, animal husbandry, health care, environmental sustainability, and the food and cosmetic industries, offering broad prospects for value addition and rural development.

Introduction

Mulberry is a multipurpose tree and has high potential economic value other than sericulture, because it has many unique and special features. Apart from being the sole food plant of mulberry silkworm, mulberry can also be exploited for several other biological and industrial purposes. Multipurpose use of mulberry is well documented by different workers. Mulberry can serve several important requirement namely, food fodder, fuel and fibre.



(i) Fodder use:

Mulberry is used as a fodder plant. The rich protein and carbohydrate content of mulberry leaves serves as a good green fodder like other fodder to livestock. The unused leaf after feeding to the silkworm is used as fodder to increase the milk of livestock. It is calculated that one ha mulberry garden sustains 3 - 4 milch animals, which adds additional income of Rs.8, 000 – 10,000 to a family. CSGRC, Hosur has identified some mulberry accessions suitable for fodder (ME-0066, 0065, MI-0012, 0014, 0162, 0173, 0178, 0310, 0383 and 0387).

(ii) Fuel use:

Mulberry is fast growing plant and sustain repeated pruning to produce huge biomass. The twigs and leaf are used as fuel for cooking. It is estimated that from one ha of mulberry garden about 10 –12 ton of stems and twigs are available per year which can meet the annual requirement of a family of 6 – 8 members. More than, 5 kg biological yield /plant was obtained from 142 mulberry accessions which are suitable for fuel use.

(iii) Basket mulberry:

The mulberry variety used for making baskets is popularly known as basket mulberry. The characteristic features of the mulberry variety is that the stem is resilient, flexible, fast growing, more number of branch/plant, small leaf, shoot is higher than leaf (biological yield) and the twigs easily bend for preparation of basket. In Sujampur, Pathankote, and Dhar villages of Punjab, Haridwar in Uttaranchal and Jammu & Kashmir, the mulberry twigs are used for basket and handle of agricultural implements. The farmers usually plant mulberry in their backyard, roadside, bund areas and other fallow land to get sufficient twigs of mulberry and used them for additional income as well as part time job for family members. The basket is used to carry various household purpose, transportation of manures, vegetables, cereals etc. and other works. The accessions suitable for this purpose are identified (MI- 0026, 0059, 0205, 0529, 0531 and ME-0259).

(iv) Fruit use:

Mulberry provides delicious and nutritious fruits which are very popular in North and South India. *M. laevigata* varieties have long fruits which are seedless and sweet. Therefore, it has commercial value. *M. alba* produces white fruits, which are very sweet to taste. Fruits are sold from March –May at Mahabaleshwar, Delhi, Dehradun, Rajasthan, Almora and other adjacent areas. Mulberry fruits contain high carbohydrate besides vitamins and minerals and they are used for jam, jelly, juices and other products. Mulberry fruit juice helps to prevent high fever, dyspepsia and melancholia. The mulberry may be exploited as minor fruits. CSGRC, Hosur has identified a good number of fruit yielding mulberry accession (MI- 0118, 0171, 0172, 0249, 0300, 0362, 0380, 0497, 0501, 0505, 0507, 0512, 0516 and 0673).

Food items	Uses
Squash	Fruits of <i>M. alba</i> used for the preparation of spiced squash and appetizer.
Pastry	Buckwheat flour, hulls, inulin and chokeberry along with <i>M. alba</i> extraction used for the production of pastry which is rich in fiber and low in calorie
Chocolate	From dried <i>M. nigra</i> fruit obtained anthocyanins can be

	used in chocolate preparation.
Pasta	Extraction of <i>M. nigra</i> having hypoglycaemic effect, it reduces the glycemic index is vastly used to produce pasta
Minced meat	Shelf life of minced meat increased by methanolic extraction of mulberry leaves
Yogurt	Anthocyanins of <i>M. rudra</i> acts as a coloring agent of strawberry flavored yogurt.
Probiotics	For the isolation and culture of lactic acid forming bacteria <i>M. alba</i> silage is very important. These bacteria can stabilize the gastrointestinal tract microbial flora.
Fruit jam	Mixed fruit jam prepared based on ratios of 70:30 rosella and mulberry fruit extract.
Cup cake	The concentrated amount of <i>M. alba</i> paste used to prepared cupcakes.
Syrup	For the preparation of syrup <i>M. alba</i> fruit used and it can be stored for 6 months under refrigerated condition
Vinegar	<i>M. alba</i> is exploited to prepare vinegar. Karaagac et al., 2016 [31]. Alcoholic beverage Fruit of <i>M. alba</i> used to produce alcoholic beverage and also used as a raw material to brew fruit wine.



(i) Aforestation

Mulberry is a fast growing species, available in forest and cultivated form. *M.serrata* and *M.lavigata* are found drought tolerant and therefore good for aforestation. In nature, it grows at high altitude, hill areas, arid, semi- arid, saline and other areas. A good number of *M. lavigata* (100 acc.) and *M. serrata* (50 acc.) collected and maintained at CSGRC, Hosur are suitable for aforestation.

(ii) Medicinal use of mulberry

Mulberry is called “Kalpavruksha”. The fruit extract is good laxative. The leaf extract is used to cure throat inflammation; the bark is used as purgative and vermifuse; the root has antihelmintic and astringent properties. Thus the different parts of mulberry i.e. root, stem, leaf, fruits and bark can be used as home medicine. Mulberry leaf cures diabetes, hypertension and diuresis. It has therapeutic value for the treatment of diseases like arthritis, dyspepsia, melancholia, nervous disorders, constipation. It has been reported as a very effective antihelmintic, antipyretic and anti inflammatory agent. Besides this, leaf extracts prevent throat infection, irritation and inflammation of throat. The bark is effective as purgative and vermifuse. The roots contains anthelmintic and cathartic properties (Suryanarayanan, 2002)

(v) Timber value

Mulberry is well known for the manufacture of sports article and toys, turnery items. The hard wood from *M. laevigata*, *M. serrata* and *M. indica* is used for manufacture of tennis-racket, and cricket bats for fine grain and polishing. The fine grains and smoothness of wood, is extensively used in manufacturing of bobbins, pullies, foot handles, toys etc. *M. laevigata* is reported as termite resistant and used as pole in house building in Andaman and Nicobar islands. Some of the accessions of *M. serrata*, *M. laevigata* and *M. indica* maintained at CSGRC, Hosur are useful for timber purpose.

(vi) Religious sanctity

M.serrata is confined to North Western Himalayan belt of India at higher altitude. *M. serrata* is worshipped at Joshimath, Pithoragarh, Hanumanchetti, Ranachetti, Pandukeshar, Almora, Nainital and other places. The giant mulberry tree, the oldest in India at Joshimath of Chamoli district where Adi Guru Sri Sankaracharya meditated, gained religious importance. The tree is revered and worshiped by the people. *M. serrata*, wild species of mulberry is available in that area and usually used for religious purpose (MI0378, 0379, 0408, 0409, 0426 and 0436)



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SUSTAINABLE MULBERRY FARMING: INTEGRATING CIRCULAR ECONOMY AND WASTE MANAGEMENT PRACTICES

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Introduction

India is the second largest producer of raw silk in the world, after China. Quality and quantity of mulberry leaf plays major role in competing globally for raw silk production. India stands second in mulberry cultivation with an area of 2,82,244 ha. The cultivation of mulberry involves various strategy including use of chemicals for number of management practices. The widespread use of chemicals in mulberry cultivation significantly contributes to a larger global environmental footprint, impacting on the soil, water quality and biodiversity. Sustainable farming concept helps to combat such implications in mulberry farming and it contribute to the economy. Sustainable Mulberry Farming is an approach that focuses on producing high-quality mulberry leaves, in a way that protects the environment, conserves natural resources, and ensures long-term productivity. With the growing concerns about climate change, soil degradation, and water scarcity, the adoption of sustainable farming methods has become essential for mulberry growers. This practice involves methods that minimize the use of harmful chemicals, optimize water and soil management, and ensure the health of the local ecosystem. Key elements include organic farming techniques, efficient irrigation methods, integrated farming practices and integrated pest management (IPM). These practices not only improve soil fertility and biodiversity but also enhance the quality and quantity of mulberry leaves, which are critical for silk production.

Sustainable soil management practices

Sustainable soil management helps maintain soil health, structure, and fertility, which are essential for mulberry growth and productivity. It helps conserve water by reducing soil erosion, improving soil water-holding capacity, and promoting efficient water use. It helps to conserve biodiversity by maintaining soil biota, reducing soil pollution, and promoting ecosystem. It helps mitigate climate change by sequestering carbon, reducing greenhouse gas emissions, and promoting soil resilience. We have to follow some principles for sustainable soil management, such as,

- Soil conservation: Minimize soil erosion and degradation through conservation tillage, mulching, and cover cropping.
- Soil fertility management: Maintain soil fertility through organic amendments, crop rotation, and integrated nutrient management.
- Soil structure management: Improve soil structure through addition of organic matter, reduced tillage, and cover cropping.
- Soil biota management: Promote soil biota through conservation tillage, organic amendments, and reduced chemical use.
- Integrated pest management: Use integrated pest management techniques like cultural, mechanical, biological control to minimize chemical use and promote ecosystem services.

Soil Management Practices in Mulberry Gardens

- Organic mulching: Organic mulch like compost, straw, leaves, and other crop residues are used to conserve soil moisture, improve soil conditions, and suppress weeds, promoting sustainable leaf yield and quality.
- Cover cropping: Cover crops like horse gram, cowpea, sun hemp, and Dhaincha are used to improve soil health and suppress weeds, and should be incorporated into the soil by plowing before flowering and the end of the monsoon.
- Integrated nutrient management: INM practice to optimize fertilizer use, reduce waste, and promote soil fertility.

Conservation tillage: Use of conservation tillage techniques to reduce soil disturbance, minimizing erosion, improved water infiltration, promote soil biota and improve soil structure

Integrated nutrient management

- Organic Fertilizers: Incorporate organic matter like farmyard manure (FYM), compost, oil cakes, vermicompost, green leaf manure, and poultry manure to improve soil structure, water-holding capacity, and nutrient availability. Apply FYM at 10 metric tons/ha in a rainfed condition and 20 metric tons/ha in an irrigated condition, preferably during pruning.
- Inorganic Fertilizers: Use of recommended doses of nitrogen (N), phosphorus (P), and potassium (K) fertilizers based on the type of mulberry cultivation and soil conditions. Apply fertilizers in split doses (e.g., 5 or 6 split doses per year) to ensure continuous nutrient supply to the plants. For rainfed condition 100:50:50 kg NPK per ha and for irrigated condition 350:120:120 kg NPK per ha.
- Biofertilizers
 - Seriphos: Use biofertilizers like Seriphos to enhance phosphorus uptake.
 - Other Biofertilizers: Azospirillum @ 20 kg/ha, phosphobacterium @ 10 kg/ha.
- Micronutrients: Apply micronutrients as foliar sprays (e.g., zinc sulfate, ferrous sulfate, borax, copper sulfate, manganese sulfate, sodium molybdate) using a high-volume sprayer.

Sustainable water management practices

Sustainable water management is crucial for maintaining the health and productivity of mulberry gardens. Mulberry gardens require significant water resources, which can be scarce in many regions. Some variety are sensitive to water quality, and poor water quality can impact plant growth and productivity. Good practices helps to maintain soil health, structure, and fertility, which are essential for mulberry plant growth. Sustainable water management reduces the environmental impact of mulberry gardens, including water pollution and habitat destruction.

- Rainwater harvesting: Collect and store rainwater for irrigation, reducing the demand on groundwater and surface water resources.
- Drip irrigation: Use drip irrigation systems to deliver water directly to the roots of mulberry plants, reducing evaporation and runoff.
- Mulching: Apply organic mulch to retain soil moisture, suppress weeds, and regulate soil temperature.

- Irrigation scheduling: Schedule irrigation based on mulberry plant water requirements, soil moisture levels, and weather conditions.
- Water quality & Soil moisture monitoring: Monitor water quality to ensure it meets mulberry plant requirements and to prevent water pollution. Monitor soil moisture levels to optimize irrigation and prevent waterlogging.
- Drought management: Implement drought management strategies, such as reducing irrigation frequency and using drought-tolerant mulberry varieties.

Sustainable pest and disease management

Sustainable pest and disease management reduces the use of chemical pesticides and fungicides, which can harm human health and the environment. It promotes ecosystem services, such as pollination, pest control, and nutrient cycling. It increases crop resilience to pests and diseases, reducing the risk of crop failure and it enhances biodiversity, including beneficial insects, microorganisms, and other organisms. Integrated Pest Management Practice approach helps in Sustainable pest and disease management that involves,

- Monitoring pest and disease populations: Regularly monitor pest and disease populations to identify potential problems.
- Identifying pest and disease thresholds: Establish thresholds for pest and disease populations to determine when control measures are necessary.
- Implementing control measures: Implement control measures, such as biological control, cultural control, and resistant varieties, to manage pest and disease populations.
- Companion planting: Plant companion plants, such as marigolds and basil, to repel pests and attract beneficial insects.
- Biological control: Use biological control agents, such as lady beetles and lacewings, to control pest populations.
- Cultural control: Implement cultural control practices, such as pruning and sanitation, to reduce pest and disease pressure.
- Resistant varieties: Plant mulberry varieties resistant to pests and diseases.

Sustainable disease management reduces the use of chemical fungicides, which can harm human health and the environment. Such practices involves,

- Sanitation and hygiene: Implement sanitation and hygiene practices, such as disinfecting tools and equipment, to reduce disease spread.
- Pruning and training: Prune and train mulberry plants to promote air circulation and reduce disease pressure.
- Biological control: Use biological control agents, such as Trichoderma and Bacillus, to control disease-causing microorganisms.
- Cultural control: Implement cultural control practices, such as adjusting irrigation and fertilization, to reduce disease pressure.
- Resistant varieties: Plant mulberry varieties resistant to diseases. E.g., Kanva-2, S-54, and MR-2 are known for their resistance to leaf spot, while Kanva-2 is also moderately resistant to leaf rust and powdery mildew.

Intercropping in mulberry

Integrated mulberry cultivation with other crops or trees to enhance biodiversity and ecosystem services. Intercropping can lead to higher yields in both the main crop (mulberry) and the intercrop. Leguminous intercrops, like pulses, fix atmospheric nitrogen, enriching the soil and reducing the need for chemical fertilizers. Intercropping promotes efficient use of land and other resources, especially in areas where land is limited. Growing intercrops alongside mulberry can generate additional income for farmers, diversifying their income sources. Intercropping can help suppress weed growth, reducing the need for manual weeding. Some intercrops can help reduce pest and disease incidence in mulberry. Intercropping can contribute to the economic upliftment of farmers, particularly in areas where sericulture is a primary livelihood.

Suitable Intercrops can be grown along with mulberry are,

- Pulses: Green gram, black gram, horse gram, soybean, cowpea, and cluster bean are good options for intercropping with mulberry.
- Other Crops: Garlic, onion, carrot, turmeric, and gingelly (sesame) have also been successfully intercropped with mulberry.
- Vegetables: Intercropping with vegetables like onions and garlic can provide additional income for farmers.

Circular economy by sustainable mulberry cultivation practices

Sustainable mulberry cultivation plays a key role in the circular economy by promoting resource efficiency, waste reduction, and regenerative practices. By integrating waste-to-resource

strategies, carbon sequestration, and multiple revenue streams, mulberry cultivation aligns with circular economy principles, making it a highly sustainable agricultural model.

- **Zero Waste Approach:** Mulberry cultivation supports the silk industry, where leaves are used for silkworm feed. Pruned branches, leftover leaves, and fruit residues can be used for composting, biochar, or animal feed.
- **Eco-Friendly Dyes & Extractives:** Mulberry bark, wood, and fruit contain natural dyes and bioactive compounds. These can replace synthetic dyes in textiles and be used in cosmetics, food, or medicine.
- **Carbon Sequestration & Soil Health:** Mulberry trees absorb CO₂, contributing to climate change mitigation. Their deep root systems prevent soil erosion and improve land fertility.
- **Biomass & Bioenergy:** Pruned wood and leaves can be converted into biogas, biochar, or pellets for renewable energy. This reduces reliance on fossil fuels.
- **Sustainable Agroforestry & Land Use:** Mulberry can be intercropped with other plants, increasing biodiversity. It fits well into agroforestry systems, reducing the need for synthetic fertilizers and pesticides.
- **Value Addition & Rural Livelihoods:** Besides silk, mulberry fruit is used for juices, jams, and nutraceuticals. Mulberry leaves are used in herbal teas and medicinal extracts. This ensures income diversification and boosts local economies.
- **Water Efficiency:** Mulberry trees are drought-resistant and require less water compared to other crops. Proper mulberry farming techniques help in water conservation.

Waste Utilization in Mulberry Cultivation

Mulberry cultivation generates various organic wastes, including leaves, branches, fruit residues, and bark. These byproducts can be repurposed efficiently to support sustainability and align with circular economy principles.

1. Mulberry Leaves & Stem

- **Silkworm Feed:** The primary use of mulberry leaves is as food for silkworms in sericulture. Even fallen or rejected leaves can be fed to livestock, reducing waste.
- **Organic Fertilizer & Compost:** Decomposed leaves and stems enrich compost and biofertilizers. They improve soil health and microbial activity.

- **Mulberry Leaf Tea & Extracts:** Dried leaves are used in herbal teas and supplements due to their antioxidant properties. Rich in DNJ (1-Deoxynojirimycin), which helps regulate blood sugar.
- **Animal Feed:** Fresh or dried leaves and twigs can be used as nutritious feed for cattle, goats, and rabbits.

2. Pruned Mulberry Branches & Bark

- **Biochar & Biomass Energy:** Pruned branches and twigs can be converted into biochar, which improves soil fertility and carbon sequestration. They can also be pelletized for biofuel, reducing reliance on wood from forests.
- **Mulberry Paper & Fiber:** Mulberry bark is traditionally used to make handmade paper (e.g., Japan's Washi paper). It is also used for natural fiber extraction for textiles and handicrafts.
- **Dye Extraction:** Bark and branches contain natural tannins and flavonoids, useful for eco-friendly textile dyes.

3. Mulberry Fruits & Residues

- **Food Processing Waste Utilization:** Overripe or damaged mulberries can be used in juices, jams, and wine. Seeds are rich in omega fatty acids and can be extracted for edible mulberry seed oil.
- **Nutraceutical & Pharmaceutical Applications:** Fruit residues can be processed into antioxidant-rich extracts for supplements. Mulberry residues contain anthocyanins and flavonoids, beneficial for skin and health products.
- **Animal Feed & Fermentation:** Fermented mulberry fruit pulp can be used in probiotic feed supplements for livestock.

4. Soil & Water Conservation

- **Mulberry-Based Green Manure:** Leaf litter and organic mulch from mulberry trees improve soil structure and water retention.
- **Wastewater Treatment:** Mulberry roots have phytoremediation properties, helping absorb heavy metals and purify soil and water.

Conclusion

Sustainable mulberry farming is a vital approach to promotes eco-friendly cultivation, resource efficiency, and waste management. By integrating organic farming techniques, soil

conservation methods, and circular economy principles, mulberry farming minimizes environmental impact while maximizing productivity. Through zero-waste utilization, byproducts such as leaves, branches, and fruit residues are repurposed for silkworm feed, organic fertilizers, bioenergy, and natural dyes, ensuring sustainability across multiple industries. Additionally, mulberry farming contributes to carbon sequestration, biodiversity enhancement, and rural economic development, making it an ideal model for sustainable agriculture. By adopting innovative waste management strategies, renewable energy solutions, and policy-driven support, mulberry farming can continue to thrive as an environmentally and economically sustainable practice. Encouraging such approaches will enhance climate resilience, resource circularity i.e., Circular economy and long-term agricultural sustainability.

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BIOGAS PRODUCTION FROM SERICULTURE WASTE: TURNING SILK INDUSTRY WASTE INTO GREEN ENERGY

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Abstract

Sericulture, a vital rural industry in India, produces significant volumes of biodegradable waste such as mulberry leaf residue, silkworm litter, pupae, and cocoon reeling waste. Usually, these organic by-products have not been widely used, which is concerning for the environment, yet they have a great chance to be bioenergy generators. This article explores the prospects of converting sericulture waste into biogas through anaerobic digestion. It discusses the types of sericultural waste, their biogas yield potential, and suitable digester models ranging from household units to community-scale plants. Through case studies from Karnataka, Himachal Pradesh, and West Bengal, the article highlights the socio-economic and ecological benefits, including energy self-sufficiency, organic manure production, and rural women's empowerment. It also addresses the challenges of adoption, such as limited awareness and infrastructural gaps, while emphasizing the need for supportive policies and technological innovation. The article concludes by positioning biogas production from sericulture waste as a sustainable solution that aligns with circular economy principles, enhances rural livelihoods, and contributes to climate resilience.

Silk Industry's untapped resource

For many centuries, rural India's income has relied heavily on the silk business. Because more than 6 million people take part in the industry, India is the second-biggest producer of silk, adding almost 18% to world silk reserves. The process of making silk takes the silk from the mulberry plant all the way to the silk unit, is very detailed, hard work, and is based on tradition.

Yet, as silk is produced, a big problem has been ignored is that the large amount of wasted resources. In the past, the remains of mulberry leaves, silkworms, pupae, and cocoons were usually thrown away, burned, or handled inefficient ways through composting. On the other hand, more people are paying attention to bioenergy and circular economy ideas, changing how things work. Currently, wastes are being viewed as useful materials to create bioenergy in the form of biogas. This article discusses how biogas from sericulture waste helps protect the environment and also gives people in rural areas chances for self-sufficiency in energy, farming with organic methods, and having various income sources.

Understanding Biogas: Science of converting waste into energy

Biogas is mainly made of methane (CH_4) and carbon dioxide (CO_2) and also contains very little hydrogen sulfide and water vapor. Bio-methane is made when organic materials are decomposed in the absence of air, in a closed biogas digester.

The process of anaerobic digestion happens in three important phases.

- I. Hydrolysis
- II. Acetogenesis
- III. Methanogenesis

During **hydrolysis**, complex organic molecules are turned into basic sugars, amino acids, and fatty acids. In Acidogenesis and **Acetogenesis**, the simple compounds give rise to alcohols, volatile fatty acids, hydrogen, and CO_2 . In **Methanogenesis**, Microbes called methanogens change these products into biogas.

Why Biogas?

- Environment friendly: Helps reduce gas that causes global warming and avoids soil and water contamination.
- Cost-effective on fuel and uses less of natural fossil fuels.
- Dual output means it makes gas for energy and digestate as organic manure.

Sericulture waste: A rich Neglected source

Every part of the sericulture process creates certain types of waste. This is what it looks like when unpacked.

1. Waste left after decomposing mulberry leaves

Although silkworms only eat mulberry leaves, the percentage of leaves they eat from the harvest is about 60 to 70 percent.

The remaining leaves, stems, and fallen litter are usually discarded or left to decay.

2. Silkworm litter (Bed Refuse)

Includes leftover leaves, silkworm faeces, and partially eaten material. Nitrogen and organic carbon are both in large amounts.

3. Silkworm Pupae Cloth

After the process, silk is obtained and the pupae remain. Rich in proteins and lipids, they degrade quickly, emitting foul odours if not managed.

4. Cocoon and Reeling Waste

Cocoons that are damaged or do not work for the process of reeling. There are residues in hot-water reeling called gelatinous and fibrous wastes.

Since they are biodegradable and rich in organic components, they are the best kind of wastes for anaerobic digestion. According to research by Jayaram and Raju (2021), the ministry estimates that about 3.5 lakh tonnes of sericulture waste in India every year, yet most of it is not put to good use.

Biogas potential of Seri-Waste

Studies and trial projects have verified that there is a high amount of biogas that can be produced from sericulture waste. After digging out, silkworm pupae can turn into biogas that gives off nearly 0.06 m³/kg and contains over 65% methane. Silkworm litter amount is 0.035–0.045 m³/kg, so it can be fed steadily to household digesters. For mulberry and pupae mixed with cow dung, their levels become stable, which improves the quantity and quality of the compost. Rao et al. (2018) studied at the Central Silk Board (CSB) and stated that a biogas plant with input of 20 kg daily could meet the cooking needs of a family.

Use of Biogas Plant Models in Sericulture Waste

Based on the size of their business and the resources they have, farmers may apply different models.

1. Family-sized Fixed Dome Digesters:

- The tank's capacity is between 1 and 3 cubic meters.
- Suitable for individual rearing houses.
- Cost: ₹20,000–₹35,000 (with government subsidies)

2. Community Biogas Plants

- A tank can hold between 10 and 50 m³.

- Good for creating clusters or societies in the silk industry
- Carry out daily waste pick-up services in different localities.

3. Portable PVC digesters

- An alternative for people who want to adopt for a low price
- Quick and easy to set up and maintain.

In general, plants practice semi-continuous feeding and are teamed up with slurry separation units for handling digestate well.

Success stories

1. The district of Mandya, in Karnataka

All farmers growing mulberry and silkworms got 2m³ biogas plants funded by the RKVY scheme. We provide feed daily to the silkworm excreta and cocoon wastes.

Result: There was a 40% decrease in the usage of LPG. Mulberry plots are improved by using digestate as natural fertilizer. Intercrops such as legumes get improved with slurry included in planting.

2. Bilaspur is found in the province of Himachal Pradesh

The women leaders of a self-help group arranged for Krishi Vigyan Kendra (KVK) to help install a 5 m³ community digester. The farm uses the waste from the cocoon of 12 families as input. Can save approximately ₹800 per month for every household in terms of fuel cost. Mushroom farming with the digestate can also be done.

3. Murshidabad belongs to West Bengal

With the help of the government, the priest's Waste Unit converted its waste into electricity which could be used to dry silk. An amount of CO₂ is reduced by half, and now the kitchen runs on biogas.

Benefits beyond energy

1. Organic manure that contains many essential nutrients

The digestate from biogas plants is packed with nitrogen, phosphorus, potassium (NPK), and micronutrients. When applied in mulberry fields, the leaf yield increases by 15–20% and better air circulation in the soil and the soil's ability to hold water.

2. Pollution Control

Unguided handling of sericulture garbage causes the following:

- Soil contamination

- Foul odour and fly menace
- Contamination caused by water runoff

Using a biogas plant prevents these risks since it safely manages waste and changes it into fuel.

3. Women Empowerment

Since women are primary workers in sericulture, biogas-based systems reduce drudgery, especially in fuelwood collection and cooking, while offering new income streams.

Challenges in adoption

Despite its promise, widespread adoption is slow due to:

- The biggest issue is that it is hard for small farmers to meet the initial expense of adopting new technologies.
- Very few people know about the value of biogas in sericulture.
- Lack of technical skills in how to operate and maintain the enterprise.
- Inadequate support in repair, servicing, and component supply.
- Also, if weather is freezing and plants are not kept warm enough, gas savings might decrease

Government support and policies

Many government actions are encouraging the use of biogas systems.

- The NBOMP from the national government provides funding support and education.
- RKVY, MGNREGA, and KUSUM schemes: Can be converged for infrastructure support.
- State Sericulture Boards: Karnataka, Tamil Nadu, and West Bengal have launched pilot programs integrating biogas with sericulture clusters.
- CSRTI and KVKs regularly organize hands-on training for farmers on biogas technology, waste handling, and slurry management.

Upcoming potential: Combining Circular Economy and logistics

- To properly make use of sericulture waste for biogas:
- Promoting clusters can be done best via Farmer Producer Organizations.
- If buildings have IoT-driven digesters and smart gas meters, they can streamline their activities and notice problems right away.
- Merging settings of vermicomposting and aquaponics can boost the overall output.

- Registering carbon credits and turning reductions into financial rewards is a way to get more income.

Further research is needed to improve the microbial efficiency, especially for high-protein pupae waste, and to scale models for semi-commercial applications.

Conclusion

As energy and ecology remain important topics, producing biogas from sericulture waste is an important yet unnoticed change. It turns what was once a burden into a bounty—providing energy, enhancing soil health, reducing pollution, and supporting livelihoods.

Connecting clean energy to rural industries combines the old with the new in an ideal way. With more people using it, Indian sericulture could be the source of precious silk and an inspiration for eco-friendly and stronger rural communities.

Let us reimagine the journey of silk, not just as fabric for fashion, but as a path to sustainability, with every waste thread fueling a brighter, greener tomorrow.

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MUSHROOM CULTIVATION USING SERICULTURE WASTE: A GREEN PATH TO SUSTAINABILITY

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Abstract

This article explores the innovative integration of mushroom cultivation with sericulture waste, presenting a sustainable solution for agricultural byproduct management. By utilizing mulberry twigs, silkworm excreta, and pupae residues as growth substrates, farmers can cultivate high-value mushrooms like oyster, shiitake, and medicinal Ganoderma species. The approach demonstrates a circular economy model that converts waste into economic opportunity while addressing environmental concerns. Key benefits include enhanced farm productivity through dual income streams (silk and mushrooms), improved soil health via spent substrate composting, and increased food security through protein-rich mushroom production. With low technical barriers and minimal investment requirements, this waste-to-wealth strategy offers rural communities a practical pathway to sustainable agriculture. The article details optimal substrate formulations, cultivation techniques, and market potential, positioning sericulture-mushroom integration as a replicable model for agro-innovation in developing economies.

Introduction

Sericulture, the age-old practice of silk production, generates staggering amounts of organic waste that has long plagued rural landscapes across Asia. For centuries, farmers have struggled with the mounting piles of silkworm excreta, mulberry twigs, and pupae byproducts - until a revolutionary solution emerged from nature itself. Mushroom cultivation, with its remarkable ability to thrive on diverse organic substrates, has unlocked the hidden value in these

sericulture wastes, creating an extraordinary circular economy model. This innovative pairing addresses multiple challenges simultaneously: it eliminates hazardous waste disposal practices, provides farmers with a lucrative secondary income stream, and produces nutritious food - all while requiring minimal investment. Research shows that mushrooms grown on sericulture waste not only match but often surpass conventional substrates in yield and quality, with oyster mushrooms demonstrating particularly impressive results. The implications extend far beyond individual farms, offering a scalable template for sustainable rural development that combines traditional knowledge with modern agro-innovation. As climate-smart agriculture becomes increasingly crucial, this waste-to-wealth model stands as a beacon of hope, demonstrating how agricultural byproducts can be transformed from environmental liabilities into economic assets while strengthening food security and supporting rural livelihoods.

TYPES OF SERICULTURE WASTE USED

The diverse byproducts of sericulture offer a veritable treasure trove of substrate materials for mushroom cultivation, each with unique nutritional properties that can be strategically utilized. Mulberry twigs and branches, generated during regular pruning operations, serve as an excellent lignocellulosic base for mushroom substrates - when properly chipped and composted, their high cellulose and lignin content (approximately 40-50% cellulose, 20-30% lignin) provides the perfect structural matrix for mycelial colonization, particularly for wood-loving species like oyster mushrooms (*Pleurotus* spp.). Silkworm litter, a composite of excreta (commonly called "silkworm manure") and bed refuse, is remarkably nitrogen-rich (N content 2.5-3.5%), making it a valuable amendment when blended with carbon-dominant materials at 15-20% ratio to achieve the ideal C:N balance for fungal growth. The protein-packed silkworm pupae waste, containing 45-55% crude protein and essential amino acids, undergoes thermal composting to create a potent organic supplement that boosts both substrate fertility and mushroom yields. Perhaps most intriguing is the reeling waste comprising chrysalis residues and sericin proteins - after controlled biodegradation, this material releases not only valuable nitrogen (3-4%) but also critical minerals like potassium, phosphorus, and magnesium that enhance mushroom fruit body development. Advanced substrate formulations often combine these components in specific ratios (e.g., 60% mulberry twigs, 20% silkworm litter, 15% pupae compost, 5% reeling waste) to create optimized growth media that outperform traditional substrates in both colonization speed (reduced by 3-5 days) and biological efficiency (increased

by 15–25%). This meticulous utilization of sericulture waste streams exemplifies the principles of circular bioeconomy, transforming what was once considered agricultural debris into high-value mushroom production inputs.

MUSHROOM CULTIVATION PROCESS

The cultivation of mushrooms using sericulture waste follows a meticulously controlled process to ensure optimal growth and yield.

1. Substrate Preparation

The foundation of successful mushroom cultivation lies in proper substrate formulation. Mulberry twigs, collected after pruning, are mechanically chopped into 1–2 cm pieces to increase surface area for mycelial colonization. These are then sun-dried to reduce moisture content below 15%, preventing mold formation. The dried twigs are combined with silkworm bed refuse—a nitrogen-rich mixture of excreta, leftover feed, and cocoon debris—in a 3:1 ratio (mulberry waste : silkworm refuse) to balance carbon and nitrogen levels. The substrate is then hydrated to 60–65% moisture content, ensuring sufficient water for mycelial growth without waterlogging. To eliminate competing microorganisms, the mixture undergoes steam pasteurization (65–80°C for 1–2 hours) or hot water treatment, which preserves beneficial microbes while killing pathogens.

2. Spawning & Bagging

Once the substrate cools to 25–30°C, it is inoculated with high-quality mushroom spawn (typically *Pleurotus ostreatus*, *P. florida*, or *Ganoderma lucidum*). A 5–7% spawn rate (relative to substrate weight) ensures rapid colonization. The inoculated substrate is packed into autoclavable polypropylene bags (40–50 cm height, 25–30 cm width) with 5–6 small perforations for gas exchange. Alternatively, bottle or tray cultivation can be used for commercial setups.

3. Incubation (Mycelial Colonization)

The packed bags are transferred to a dark incubation chamber with controlled conditions:

- Temperature: 24–28°C (optimal for most species)
- Humidity: 70–80% (prevent drying)
- CO₂ levels: Elevated (to promote mycelial spread)
- Within 15–20 days, dense white mycelial networks fully colonize the substrate, visible as a cottony growth. Any contamination (green/black molds) must be removed immediately to prevent spread.

4. Fruiting Induction

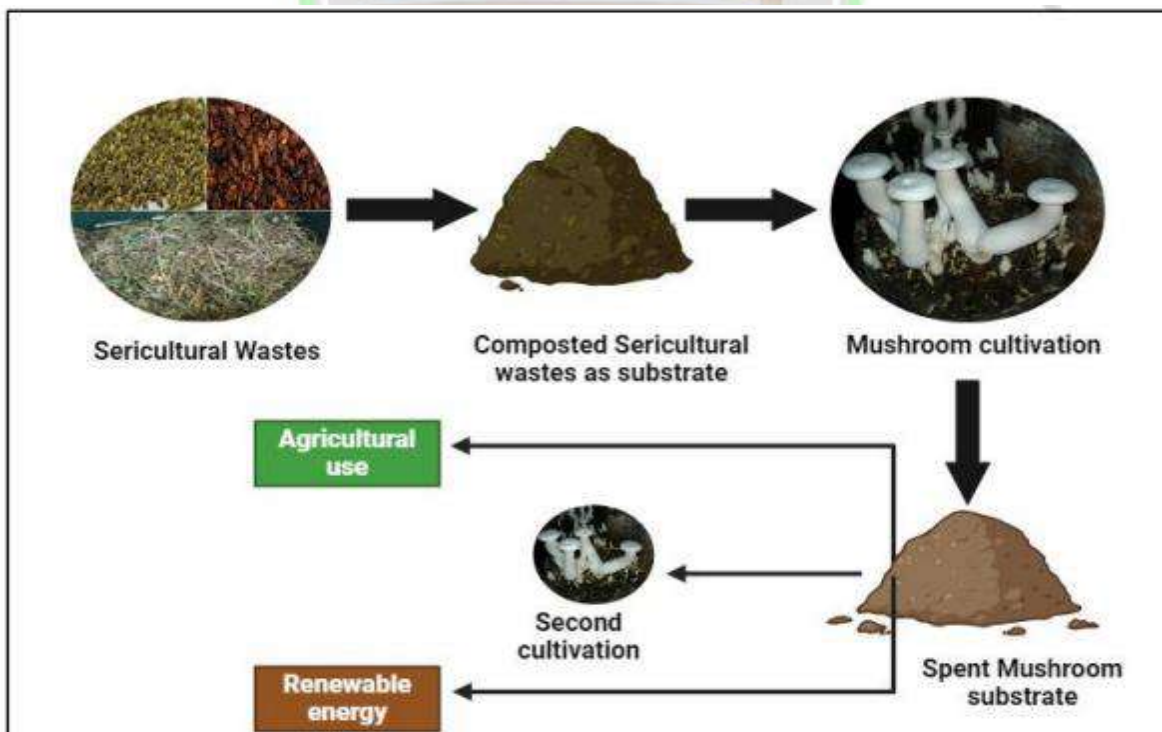
Once colonization is complete, the bags are shifted to a fruiting chamber with modified conditions:

- Light: Diffused natural or artificial light (12 hours/day) triggers pinning
- Humidity: 80–90% (maintained via misting or humidifiers)
- Fresh air exchange: Critical to reduce CO₂ and stimulate fruiting
- Temperature: Slightly lower (22–26°C) to encourage mushroom formation

Small X-shaped cuts or perforations are made on the bags to allow mushroom primordia (pins) to emerge. Within 7–10 days, tiny mushroom clusters develop into mature fruiting bodies.

5. Harvesting & Post-Harvest Management

Mushrooms are harvested just before the caps fully uncurl (button stage for maximum shelf life). A twist-and-pull technique minimizes damage to the mycelium. After the first flush (8–12 days post-pinning), the substrate is rehydrated by soaking or misting to induce 2–3 additional flushes over 30–40 days. Spent substrate, now enriched with fungal enzymes, can be repurposed as organic compost or animal feed supplement, completing the zero-waste cycle.



POPULAR MUSHROOM TYPES CULTIVATED

MUSHROOM TYPE	COLONIZATION TIME	YIELD/BAG	PICTURES
Oyster	15 – 18 days	600 – 800 g	
Paddy straw	8 – 10 days	300 – 400 g	
Milky	20 – 22 days	500 – 600 g	
Shiitake	45 – 50 days	400 – 500 g	
Ganoderma	35 – 30 days	200 – 300 g	

Conclusion

Mushroom cultivation using sericulture waste presents a sustainable, profit-generating solution that transforms agricultural byproducts into valuable food and income. This circular economy model not only resolves waste disposal challenges but also empowers farmers with additional revenue streams through low-input, high-yield mushroom farming. By converting mulberry twigs, silkworm litter, and pupae waste into nutrient-rich substrates, farmers can cultivate premium mushrooms like oyster, shiitake, and medicinal Ganoderma while improving

soil health through spent compost. The system's versatility across climates, combined with its dual benefits of waste valorization and nutritional security, makes it an ideal agro-innovation for rural communities. With minimal investment and training, this waste-to-wealth approach demonstrates how traditional industries can evolve into eco-friendly, economically viable enterprises, setting a benchmark for sustainable agriculture worldwide.

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SILKWORM PUPAL CHITOSAN: A SUSTAINABLE SUPERMATERIAL

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Abstract

Silkworm pupal chitosan, a sustainable and versatile biopolymer derived from chitin, is emerging as a revolutionary material with applications across medicine, agriculture, food preservation, cosmetics, and environmental remediation. Traditionally sourced from crustacean shells, chitosan from silkworm pupae—a byproduct of the silk industry—offers a more eco-friendly and abundant alternative. Its unique properties, including biocompatibility, biodegradability, antimicrobial activity, and film-forming ability, make it ideal for wound healing, drug delivery, food coatings, wastewater treatment, and plant defense enhancement. This article explores the structural composition, extraction process, and remarkable properties of silkworm pupal chitosan, highlighting its potential to drive green innovation while reducing industrial waste.

Introduction

While silkworms are best recognized for producing exquisite silk, their pupae and egg shells contain another valuable asset: chitosan, a remarkable biopolymer with significant promise in fields such as medicine, agriculture, food storage, and cosmetics. Chitin, the precursor to chitosan, ranks as the second most abundant polysaccharide found in nature after cellulose. Chitosan consists of randomly arranged units of N-acetyl-D-glucosamine and β -(1 $\rightarrow$ 4)-linked D-glucosamine. The creation of chitosan occurs through the natural deacetylation of chitin, resulting in a low-toxic biopolymer. Chitosan possesses unique characteristics such as biocompatibility, low toxicity, and biodegradability, leading to its use in various domains including agriculture and the food sector. Furthermore, chitosan is utilized for treatment of

wastewater as a flocking agent, as a dehydrating agent in cosmetics, as a preservative in food, in food additives, for drug delivery systems and hydrogel films in pharmaceuticals, as well as exhibiting antimicrobial properties and serving as an elicitor to enhance plant defenses. Chitin and chitosan derived from both silkworm pupae and egg shells display similar structures and compositions. Notably, chitosan sourced from silkworms demonstrated significantly higher antibacterial and antifungal efficacy compared to standard alternatives. Egg shells also represent a significant reservoir of chitin, with chicken eggs containing up to 74%. Historically, shrimp and crab shells have been the primary sources of chitosan, but silkworm pupae and egg shells provide a more sustainable and plentiful option, particularly in the sericulture (silk farming) sector where large quantities of pupae are typically disposed of as waste following silk production.

Historical records indicate that Charles Rouget is recognized for the discovery of chitosan in 1859, while the term “chitosan” was first introduced by Felix Hoppe-Seyler in 1894. Due to its unique structure, inert nature, antibacterial properties, biodegradability, flexibility, and diverse physical and chemical traits, chitosan has earned the title of a green biopolymer. As science and technology continue to evolve, chitosan is expected to play a significant role in promoting sustainability and green chemistry, driving innovations that will benefit both the environment and society at large. For each kilogram of silk produced, approximately 2 kilograms of dry pupae are generated. Given that global silk production is around 1.6 million tons, there are at least 3 million tons of pupae available annually. The chitin content found in silkworms varies based on species and sex; multivoltine silkworms generally have higher chitin levels than univoltine silkworms, and male insects typically possess more chitin than female insects. This article delves into the intriguing realm of silkworm pupal chitosan—its production, its unique attributes, and its potential to transform industries while minimizing environmental waste. From promoting wound healing to extending food shelf life and combating pollution, this often-overlooked biomaterial may be poised to emerge as a significant player in green technology.

Structural composition of chitin and chitosan:

There are three natural crystalline forms of chitin: α -, β -, and γ -chitin. These forms differ in their levels of hydration, unit cell dimensions, and the number of chitin chains in each unit cell, which results in unique physicochemical properties. The differences among these polymorphs arise from the specific alignment of the chains within the crystalline areas. The γ

form displays a configuration of two parallel strands alongside one antiparallel strand, whereas the β and α forms follow alternate configurations, respectively. Among these chitin types, α -chitin is the most common and can be harvested; it is mainly located in the cell walls of fungi and crustaceans. The only structural difference between chitin and cellulose (poly-(1-4)-N-acetyl-D-glucosamine) is that chitin contains an acetyl amine group instead of one hydroxyl group on each monomer. Chitosan, which is the final derivative of chitin, is a modified polycationic polysaccharide polymer that occurs naturally and has an average molecular weight ranging from 1 to 5×10^5 Da.

The two monosaccharides that make up this compound, N-acetyl-D-glucosamine and D-glucosamine, are connected by β (1 $\rightarrow$ 4) glycosidic bonds. Chitosan possesses reactive functional groups, including amino groups, as well as primary and secondary hydroxyl groups located at the C-2, C-3, and C-6 positions, respectively. Although chitosan does not dissolve in neutral and alkaline pH aqueous solutions, chitin is insoluble in organic solvents. Nevertheless, it easily dissolves in dilute acids (pH <6-6.5), such as acetic, formic, succinic, lactic, and malic acids, as well as in diluted HCl. This solubility can be explained by the presence of amino groups in chitosan, which give it basic qualities. The crystalline structure of chitosan is upheld by strong hydrogen bonds between the acetamide, hydroxyl, and carbonyl groups, which prevent it from dissolving in water or organic solvents.

PROPERTIES OF CHITOSAN

Physicochemical Properties Of Chitosan

The physical and chemical characteristics of chitosan, such as its solubility, molecular weight, degree of deacetylation, and viscosity, largely stem from these properties.

Molecular weight

Chitosan's molecular weight is categorized as high, medium, or low based on its range. As the molecular weight of chitosan increases, it tends to become less soluble and more viscous, often making it less suitable for various industrial applications. Low molecular weight chitosan is preferred for biological and industrial uses because of its enhanced stability and solubility. Due to its higher solubility and stability, low molecular-weight chitosan is favored in biological and industrial contexts.

Degree of deacetylation

The degree of deacetylation is a critical factor affecting the physicochemical properties,

functionality, and applications of chitosan. This relates to the arrangement of amino groups in the polymer chain. In an acidic environment, the amino group in chitosan's polymer chain imparts a positive charge. Therefore, the degree of deacetylation significantly influences solubility and viscosity levels. Chitin and chitosan can be differentiated by their degree of deacetylation. A deacetylation level above 50% typically indicates the successful conversion of chitin to chitosan.

Solubility

Chitosan is insoluble in neutral or alkaline environments but readily dissolves in acidic ones. While chitin is generally insoluble in liquids, it can be transformed into soluble chitosan through deacetylation, which contains primary amino groups with a pKa of 6.5. When chitosan dissolves in acidic solutions, the amine groups become protonated and acquire a positive charge, enhancing solubility. However, as the pH increases to 6 or higher, these groups lose their charge, resulting in chitosan becoming insoluble again. Besides pH, factors such as temperature, polymer crystallinity, molecular weight, and degree of deacetylation also affect chitosan's solubility.

Viscosity

Chitosan's viscosity is determined by its degree of deacetylation and molecular weight. A higher degree of deacetylation leads to increased viscosity, while a lower molecular weight results in reduced viscosity. Furthermore, viscosity can also be influenced by particle size and duration of storage. Viscosity is a critical measure of polymer stability in solution, as a decline in viscosity is observed during storage due to polymer degradation.

Film formation

Chitosan can create films and membranes that are beneficial for a variety of applications.

Mechanical properties

Chitosan demonstrates commendable mechanical strength and flexibility.

Biological Properties of Chitosan

Biocompatibility

Chitosan's high level of biocompatibility enables its application in medical and pharmaceutical fields. Nevertheless, the method of preparation (residual proteins may trigger allergic reactions) and the degree of deacetylation (DD) influence whether chitosan is suitable for use in physiological environments. In in vitro studies, chitosan exhibited greater cytocompatibility compared to chitin.

The interaction between chitosan and cells increases with the amount of positive ions, which in turn enhances its biocompatibility.

Biodegradability

Chitosan undergoes natural degradation by lysozyme and various proteases, allowing for its safe breakdown within biological systems. Of the eight human chitinases identified to date, three have shown enzymatic activity on chitosan. The degradation of chitosan results in the formation of non-toxic oligosaccharides of different lengths.

Bio-adhesion

Chitosan possesses remarkable bio-adhesive properties, enabling it to cling to mucosal surfaces and improve drug delivery mechanisms. In acidic conditions, it holds a positive charge due to the protonation of amino groups, which facilitates its binding to negatively charged residues in mucin, thereby enhancing its mucoadhesive qualities.

Non-toxicity

Chitosan is non-toxic to human cells, further supporting its application in food and biomedical contexts.

Antimicrobial Activity

The potent antibacterial and antifungal properties of chitosan make it effective against a variety of infections. Its polycationic nature plays a crucial role in these mechanisms. One primary theory suggests that chitosan disrupts cellular permeability, leading to leakage of intracellular components and, ultimately, cell death. Another potential mechanism involves chitosan penetrating the cell and binding to DNA, inhibiting replication and resulting in cell death. Additionally, chitosan's ability to chelate metal ions (such as Ni^{2+} , Zn^{2+} , Co^{2+} , Fe^{2+} , and Cu^{2+}) at pH levels above its pKa value helps inhibit microbial growth. By forming a dense polymer layer on microbial surfaces, chitosan restricts their access to oxygen and nutrients.

Hematostatic Property

Chitosan's hemostatic capability refers to its effectiveness in promoting blood coagulation and halting bleeding. Its positive charge facilitates interaction with the negatively charged membranes of cells and blood components, encouraging platelet adhesion and aggregation, thus speeding up the clotting process. Moreover, chitosan can establish a physical barrier at wound sites, further assisting in hemostasis by sealing the wound and minimizing blood flow.

Immune System Modulation

Chitosan has the potential to enhance immune function by activating macrophages, stimulating cytokine production, and boosting the activity of other immune cells. These interactions aid in strengthening the body's defenses, promoting quicker wound healing, and providing protection against infections.

Extraction Process

The chemicals used for chitin and chitosan extraction were Sodium hydroxide (NaOH) and Hydrochloric acid (HCl). All reagents used were of analytical grade and double distilled water was used for preparation of all solutions.

Deproteination and decoloration

Spent pupae and shells were powdered and treated in hexane to remove oil. The defatted material was added into 10% (w/w) NaOH in 1: 10 (material: alkali solution) and the solution was heated for 24 hours at 80 °C under continuous stirring at 250 rpm. After treatment, the dissolved components were removed by filtration and the solid residue was neutralized by washing with distilled water. Alkali treatment removed the proteins and also decolorized the pupae and shells.

Demineralization

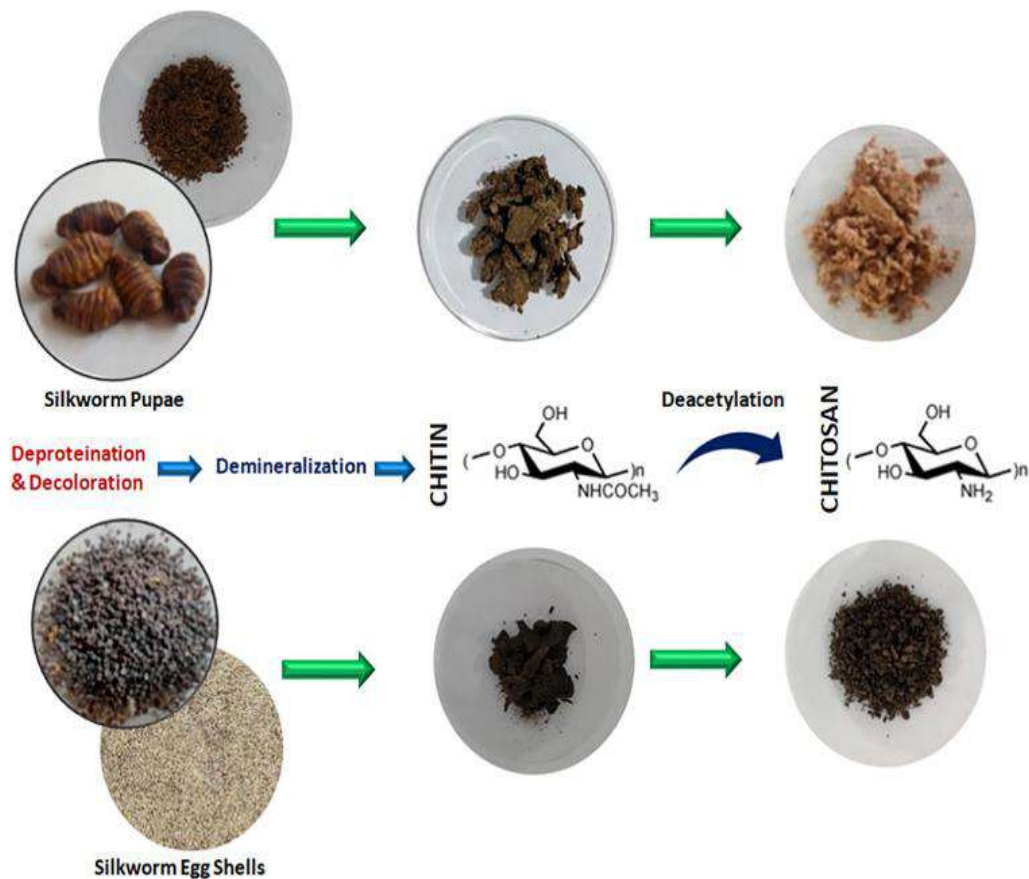
The alkali treated materials were added into 7% (v/v) HCl solution in 1:10 ratio and heated at 25 °C for 24 h to remove any minerals present. Solids (chitin) obtained after filtration were washed in distilled water and later dried at 60 °C for 24 h. Yield of chitin was calculated using:

Chitin Yield % = $\frac{\text{Weight of chitin collected}}{\text{Weight of insect powder}} \times 100$

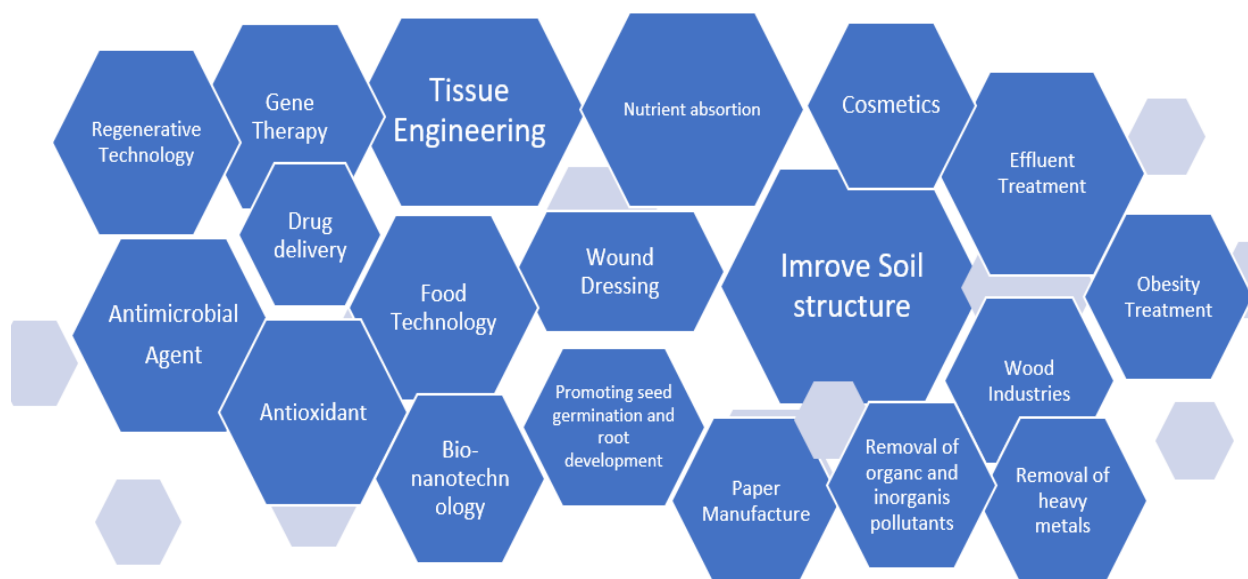
Conversion of chitin into chitosan

Conversion of chitin into chitosan was done through deacetylation. The chitin powder was treated with 55% (w/v) NaOH solution in 90 °C in a water bath at 250 rpm for 9 h. After treatment, the alkali solution was discarded and residue obtained was washed in distilled water until the pH became neutral. Yield of chitosan obtained was calculated using:

Chitosan Yield % = $\frac{\text{Weight of chitosan derived}}{\text{Weight of chitin used}} \times 100$



Applications of Chitosan:



Conclusion

Silkworm pupal chitosan represents a groundbreaking biomaterial with vast potential to transform multiple industries sustainably. As a byproduct of sericulture, its utilization not only minimizes waste but also provides a high-performance alternative to conventional chitosan sources. With exceptional antimicrobial, hemostatic, and biodegradable properties, it holds promise in medical applications, food preservation, agriculture, and environmental protection. As research advances, silkworm-derived chitosan is poised to play a pivotal role in green chemistry, offering eco-friendly solutions that benefit both society and the planet. Embracing this "supermaterial" could pave the way for a more sustainable and innovative future.

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LIGHT INTENSITY- HIGH/LOW LIGHT

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Introduction

Light is not only a major source of energy but it also is one of the environmental determinants for plant growth. The quality and intensity of the light are crucial for the growth, morphology, and physiological reactions of plants. The structure, morphology, and physiology of leaves have all been significantly impacted by changes in the light spectrum (Macedo *et al.*, 2011). The main effects of high light intensity are photoinhibition, production of ROS, Lipid peroxidation, damage of photosynthetic systems, Inhibition of enzyme activity. High radiation intensity, on the other hand, is linked to a variety of physiological and morphological traits that are suitable for the environment, such as decreased SLA to protect plants from excessive radiation exposure, increased leaf thickness through increased cell layers, or increased development of spongy and palisade tissue. This change ensures proper photosynthesis by preventing or reducing the harm caused by excessive illumination by light energy (Matos *et al.*, 2009). Excess light intensity is associated with increase in temperature of leaves which in turn induces rapid transpiration and water loss.

Effects of low light intensity

General effects of low light intensity are reduced leaf thickness, number of stomata and stomatal density, decreased transpiration rate, increased chlorophyll content, reduced CO₂ assimilation and photosynthesis. Plant height and specific leaf area (SLA) may increase with low radiation intensity. The aim of these adaptations was to increase the amount of light that could be absorbed for photosynthesis (Steinger *et al.*, 2003). Light is one of the photoreceptors in plant tissues including stems and leaves, where a variety of physiological, pharmacological, and

genetic variables can alter the synthesis of secondary metabolites (Lefsrud *et al.*, 2008). However, photosynthetic pigments are primarily responsible for absorbing light in the red and blue parts of the spectrum. Blue or red light is absorbed by plant leaves to a degree of about 90%. Accordingly, blue or red light has a major impact on photosynthetic rate, physiology, and plant growth and development (Terashima *et al.*, 2009).

Photoprotection

Plants have evolved numerous strategies, such as morphological and physiological alterations at different levels, to adapt to varying light regimes in their environment. To withstand high light plants have developed a series of light acclimation strategies. Plants have developed three main lines of defense that allow them to respond to excess light in a constantly changing environment: limiting exposure, photoprotection, and PSII repair. The plant's initial defense mechanism against excessive light consists of moving its leaves and chloroplasts away from the light and storing light-filtering and light-reflecting substances.

In photoprotection, the second line of defense, plants use cyclic electron transport, photorespiration, non-photochemical quenching, and scavenging of excess reactive oxygen species to disperse excess light energy. Following photo damage, plants begin a cycle of photosystem (mostly photosystem II) repair in the third line of defense. Chloroplasts sense stress, particularly light stress, and transfer the signal to the nucleus, where it modifies the expression of genes involved in the stress response. They are also the location of photosynthesis. Different adaptations to high light intensity are increased suberin, wax, cuticle and cell wall material; increase in carotenoid, xanthophylls and phospholipids; avoiding the sun (paraheliotropism); presence of hairs on leaves, glands on leaf surfaces and epicuticular waxes.

Photoreceptor

Another crucial component of plant responses and adaptation to high light is the regulation of gene expression (Huang *et al.* 2019). A number of photoreceptors have been linked to the detection of high light and the start of transcriptional responses. To mediate the perception of high light, the blue light photoreceptor CRYPTOCHROME1 (CRY1) is proposed as a high light receptor (Allorent and Petroustos 2017). Additional transcription factors that work in concert to control the expression of photoprotective genes include elongated hypocotyl5 (HY5), ABA insensitive4 (ABI4), MYBs, and basic helix-loop-helix (bHLH) (Jiang *et al.*, 2020).

Conclusion

General adaptations of low light intensity are increased leaf area, thin leaves, increased number of chloroplast / unit leaf, change in orientation of chloroplast, large leaves, orientation of leaves to more light (diaheliotropism), increase in number of chlorophyll molecules.

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AUTOMATED COMPOSTING SYSTEM IN FARMS

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Introduction

The development of this machine can lead to the generation of organic compost which can be sold to organic farmers at a price that will benefit both the party the one developing the machine as well the farmers. This proposed machine opens up a gate to anew side of income for the farmers as well presents an opportunity for many startups in the agriculture sector. More than 50% of India's GDP is contributed by the agricultural sector also known as the primary sector, if such an amount of GDP is contributed by this sector then development for this sector is also needed. If the development can be done for the same. It has hidden potential that no other sector has as of now in our country

Rural areas are still not connected to the urban region via roads and because of this food produced in villages cannot reach in time to the urban places where the market is available for the same. Most of the wasted food has no value and goes unsold sometimes farmers sell it even for free so that space is available for new crops. The potential of the food that is there in the market is huge, only some chunks of food reach the market and because of this, the rate for a particular vegetable or fruit is very high. Food that is wasted after production can be converted into useful compost and this paper discusses such methods to counter the wastage of food. The method proposed uses a machine to convert food waste into organic compost which can thus be used in various fields like organic farming, and many other places . Food that is wasted after production can be converted into useful compost, this paper discusses such methods to counter the wastage of food. The method proposed uses a machine convert food waste into organic compost which can thus be used in various fields like organic farming, and many other places.

KEY FEATURES OF AUTOMATED COMPOSTING SYSTEM

➤ **Grinding/Shredding:**

Many systems incorporate a grinder or shredder to break down organic waste into smaller pieces, accelerating the decomposition process.

➤ **Temperature Control:**

Sensors and heating elements monitor and maintain optimal temperatures for composting.

➤ **Moisture Control:**

Sensors and water systems ensure that the waste material has the right moisture content.

➤ **Aeration/Mixing:**

Automated systems often include features for aeration and mixing to ensure that microorganisms have access to oxygen and that the composting material is properly mixed.

➤ **Odor Control:**

Filters or other mechanisms are used to minimize odors.

➤ **Sensors and Monitoring:**

Sensors monitor temperature, moisture, and other parameters, and some systems allow for remote monitoring and control via mobile apps.

AUTOMATED COMPOSTING MACHINE

An automated composting machine streamlines the organic waste decomposition process by employing a systematic and efficient approach. Initially, the machine receives a diverse range of organic materials that undergo shredding or chopping stage, breaking down larger components into smaller pieces. Subsequently, the organic matter enters a controlled environment that regulates key factors such as temperature, moisture, and aeration. Microorganisms, including bacteria and fungi, thrive in this optimized setting, accelerating the decomposition process.

The machine monitors and adjusts these environmental variables automatically to ensure an ideal composting environment. As the microorganisms break down the organic matter, the machine facilitates the transformation into nutrient rich compost. The final product is a valuable soil amendment that can be utilized to enhance soil fertility and promote sustainable agriculture. The traditional method of composting that last for 6-12 months includes four stages of composting. Mesophilic, where bacteria and fungi break down easily to a couple of weeks;

Thermophilic, where heat-loving microorganisms break down lasting several weeks; Cooling Phase, where Mesophilic microorganisms return to break down remaining matter over a few months; and Curing Phase, where compost matures at ambient temperature, lasting several months.

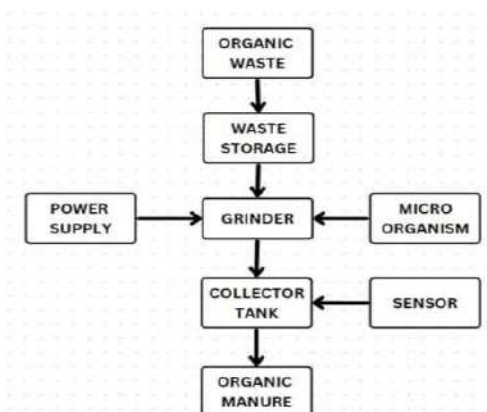
WORKING METHODS

The automated composting machine described here employs the anaerobic composting method to efficiently decompose organic waste. The process begins with the collection of organic waste in a storage tank. When power is supplied, a grinder or shredder inside the tank breaks down the waste into smaller pieces. Simultaneously, a heater within the tank is activated, raising the temperature and facilitating the evaporation of water content in the waste. The system utilizes various sensors within the tank to analyse crucial parameters such as temperature, moisture, and other environmental conditions. To initiate the decomposition process, necessary microorganisms with the appropriate carbon-nitrogen ratio are introduced into the tank. Over a period of 2-3 days, the microorganisms work in conjunction with the optimized conditions inside the tank to transform the organic waste into nutrient rich organic manure.

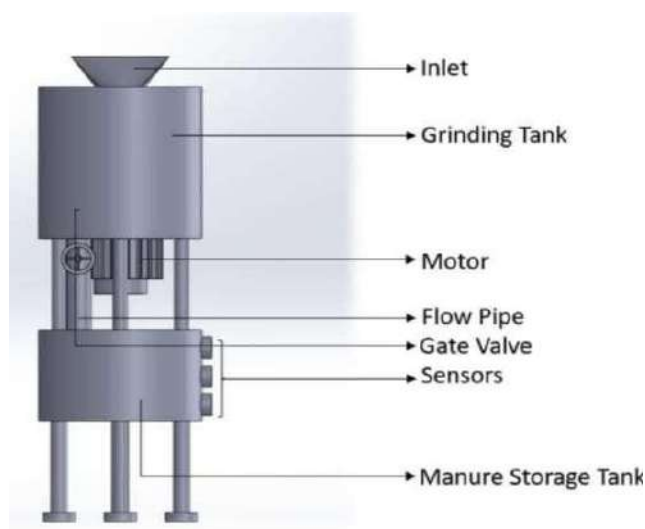
COMPONENTS USED

1. Motor ($\frac{1}{4}$ hp, 1500 rpm, 50Hz)
2. Storage Tank (20L Capacity)
3. Temperature Sensor (PT 100)
4. Soil Moisture Sensor (3.3-5V Analog)
5. Grinder with Blades Hydrolytic Bacteria(1 kg for 5kg waste).

BLOCK DIAGRAM



HARDWARE DESIGN



BENEFITS OF AUTOMATED COMPOSTING

➤ **INCREASING EFFICIENCY:**

Automation can significantly speed up the composting process compared to manual methods.

➤ **REDUCED LABOR COSTS:**

Automated systems can minimize the need for manual labor, saving time and resources.

➤ **CONTROLLED CONDITIONS:**

Monitoring and control systems allow for precise adjustments of temperature, moisture, and other parameters, optimizing the composting process.

➤ **REDUCED ODOR:**

Controlled composting conditions can minimize the production of unpleasant odors associated with waste decomposition.

➤ **SPACE EFFICIENCY:**

Automated systems can be designed to fit into smaller spaces, making them suitable for various locations.

➤ **VERSATILITY:**

Automated systems can handle a wide range of organic waste materials.

Conclusion

The development of this machine can lead to the generation of organic compost which can be sold to organic farmers at a price that will benefit both the party the one developing the machine as well the farmers. This proposed machine opens up a gate to a new side of income for the farmers as well presents an opportunity for many startups in the agriculture sector.

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SCOPE AND IMPORTANCE OF MEDICINAL AND AROMATIC CROPS

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Abstract

Medicinal and aromatic plants play a significant role in the life of people and are present in innumerable forms. In Indian traditions, all the plants in this earth are considered as medicinal. Medicinal plants have played a significant role in various ancient traditional systems of medication such as the Chinese, Ayurvedic, Unani, and their secondaries in many Asian countries. They also generate income to the people of many Asian countries who earn their livelihood from selling collected materials from the forest, or by cultivating on their farms.

However, a simplest definition of the medicinal plant would be “Medicinal plants are those plants which are used in official and various traditional systems of medicines throughout the world”. Medicinal plants are plants that provide people with medicines - to prevent disease, maintain health or cure ailments. In one form or another, they benefit virtually everyone on earth. No exact definition of Medicinal Plant is possible. There are related issues, such as for nutrition, toiletry, body care, incense and ritual healing. Aromatic plants are a special class of plants used for their aroma and flavour. Many of them are exclusively used also for medicinal purposes in aromatherapy as well as in various systems of medicine. Similarly a number of medicinal plants also produce essential oils as well as being used for perfumery. Medicinal plants still continue to

make important contributions to healthcare and livelihoods. Nearly 80% of the world population use traditional medicine, mainly medicinal plants, to cure illnesses and ailments.

Introduction

India has been considered as treasure house of valuable medicinal and aromatic plant species. Ministry of Environment and Forests have identified and documented over 9500 plant species considering their importance in the pharmaceutical industry. The diverse Agro-climatic situations in the Region offer excellent scope for growing different horticultural crops like fruits, vegetables, spices, plantation crops, medicinal and aromatic plants. Medicinal and aromatic plants constitute a major segment of the flora, which provides raw materials for use in the pharmaceuticals, cosmetics and drug industries. The indigenous systems of medicines, developed in India for centuries, make use of many medicinal herbs. Plants have been used since ancient times of all civilizations and cultures, mostly as home remedies for treating seasonal flu viruses, cough, cold, stomachache, sore throat and headaches. Besides, the aromatic plants are still used in making perfumes, because of their pleasant smelling flowers, in cooking because of their strong flavors, and liquor industries. At the present there are used many herbal treatments that are becoming very popular in the society because of their efficiency and less side effects. The medicinal and aromatic plants are less expensive, more available and have potential to control disorders. According to use of these plants is also a potential material for maintaining good health and conditions, not only for a remedy for specific diseases and also play a vital role in national economy.

Medicinal plants

According to the World Health Organization, "a medicinal plant is any plant which, in one or more of its organs, contains substances that can be used for therapeutic purposes, or which are precursors for chemo-pharmaceutical semi synthesis".

Aromatic plants

The plants possess Odiferous and volatile substances, which are extensively used in perfumery, food flavouring, cosmetics and allied industries.

Medicinal and Aromatic Plants have been a major source of health care since time immemorial. Medicinal and aromatic plants (MAPs) are traded as such in bulk from many developing countries for further value addition in developed countries.

Advantages

As compared to the traditional crops, the cultivation of medicinal crops has many advantages. These include:

- Medicinal crops provide better returns than traditional crops
- Have very high domestic and export demand
- Fetch better prices in the market
- Could be stored for a long time, and sold at a time when better prices prevail in the market
- Are the largely drought tolerant, and not easily grazed by animals
- Have low incidence of pest attacks and diseases
- Require minimum resources, therefore the cost of cultivation is lower compared to the traditional crops
- Could be raised as inter-crops, along with traditional crops, and also on degraded lands.

Constraints

There is an urgent need to give attention to the following aspects:

- Development of a package of improved practices for cultivation of these aromatic crops.
- Making availability of good quality planting material of high yielding and short-duration (in Case of menthol mint with less water need) varieties
- More demonstration / extension efforts,
- Better access to timely and adequate credit,
- Access to timely market information,
- Establishment of regulated market
- Introduction of minimum support price
- Contract farming,
- Establishment of testing facilities

Scope of medicinal and aromatic plants

India has different agro-ecological zones suitable for growing different medicinal and aromatic plants, which are in demand. However, systematic efforts will need to push this particular sector agro-ecological zone wise. The plant species will have to be identified and their package of practices will be developed. Identification of species will be important criteria

for marketing.

Planting material of known varieties

Since availability of quality planting material will be essential items of future development programme the farms of the State Agricultural Universities and Department of Agriculture and nurseries of Department of Horticulture should undertake the programme of collection and conservation of different species of medicinal and aromatic plants prevalent in the region and their multiplication on a large scale. The help of KVKs and some of the NGOs will also be important in this endeavor.

Cropping System

Many of the medicinal trees will need gestation period of 8-10 years for economic production. The farmers will need the **cropping system**, which will be suitable for giving him economic return from first year onwards. Therefore, inter cropping with species of shrubs and trees will be very much essential.

Post-harvest technology

The post-harvest technology for medicinal and aromatic plants is necessary since the plants after harvesting in green stage, if stored unprocessed for want of purchaser may get contaminated with fungi which may impair the quality of the final product. Therefore, post-harvest technology for plants their grading and packaging and method of storage should be developed.

Marketing of product

It is experienced that the farmers get convinced about the potential of profit from growing medicinal and aromatic plants. However, once they enter into business they get frustrated because of disorganized market. Therefore, concentrated efforts will be needed to organize marketing of the product produced by the farmers.

Opportunities

Medicinal and Aromatic Plants offer several opportunities towards developing agri-entrepreneurship in various ways. Some of these are enumerated as under:

1. The farmer's holding small land can grow these crops in rotation or as intercrop with cereals or vegetable crops to enhance per unit area return. Some of the MAPs are also suitable for cultivation in degraded salt-affected soils, stressed conditions and as under crops in orchards thus ensuring optimal use of the available land and other resources to the

economic advantage of the growers.

2. Putting up of the processing facilities in the aromatic plants growing areas is another income generating opportunity for a farmer who can extend the facility to the fellow growers.
3. Production of truthfully labelled seeds and propagules in collaboration with the research organizations can open new avenues in the area where possibilities of MAPs cultivation are gaining momentum.

Global marketing opportunities

Export opportunities of natural products are tremendous, as the world is looking towards natural sources for the purposes of therapeutic use as well as nutritional dietary supplements.

The global herbal remedies market can be classified into five strategic areas:

1. Phyto-Pharmaceuticals - the plant based drugs containing isolated pure active compounds used to treat diseases
2. Medicinal Botanicals / Dietary Supplements - the whole plant or plant-part extracts used for maintenance of health by affecting a body structure and its function
3. Nutraceuticals - the food containing supplements from natural (botanical) sources, that deliver a specific health benefit, including prevention and treatment of disease
4. Cosmeceuticals - the cosmetic products which contain biologically active ingredients having an effect on the user
5. Herbal raw material

Quality management

➤ Technologies to detect various adulterants and monitor the quality of the produce

Protocols to assess the quality and certification of products

➤ Information on safe waiting period/pre harvest interval for the pesticides application

Technologies to extract high value compounds of industrial demands

Future prospects

Medicinal and aromatic plants form a numerically large group of economically important plants, which provide basic raw materials for medicines, perfumes, flavours and cosmetics. These plants and their products not only serve as valuable source of income for small land holders and entrepreneurs but also earn valuable foreign exchange by way of export.



Conclusion

The role of medicinal and aromatic plants is changing continuously in accord to a period and the role expands such as cure of disease to prevention of disease. The accumulated massive knowledge, information, and materials should be shared in the whole world and go down to generation to generation.





SHRINK PACKAGING IN FOOD PROCESSING

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Introduction

Shrink packaging is a technology of using with heat shrinkable film to wrap goods, then heating, film wrapping tightly goods by shrinking according to certain proportion [1]. Shrink packaging has many characteristics: It can pack special products which are difficult to pack by general method; Its film generally is transparent and can display the appearance of the product after packaging; It can package varies kinds of or more pieces of products together easily, and sometimes can save packing box with the help of shallow platter; It can prolong the shelf life of food therefore easy to store; It is good seal, moisture proof, antifouling and antirust so easy to stack in the open air and save storage space; Its packaging technology and equipment are simple and general, easily to realize mechanization, and partially to replace the carton and wooden box; It can be used to pack large volume of product on the scene; Its film have cushioning properties and toughness so it can take effect of cushioning packaging, and therefore reduce the packaging cost .

Currently shrink packaging has been widely used in varieties of goods of sales packaging and transport packaging among the specialised plastic packaging systems, shrink packaging or commonly known as shrink wrapping and stretch wrapping are very common and widely used. Though there are some apparent similarities in the two systems, in overall analysis, they are considered to be totally different in terms of material and operation. In the case of shrink wrapping, shrink film is used as the basic material and heat forms an important part of the operation, whereas, in the case of stretch wrapping, stretch film is used as the basic material and

no heat is applied during the operation. Shrink Wrapping is done in 3 or 4 stages, namely:

- Wrapping (sleeve wrapping or over-wrapping)
- Sealing (necessary only for over-wrapping)
- Shrinking (with application of hot air), and
- Cooling

Plastics used for Shrink / Stretch Wrapping Shrink and stretch wrapping can be quite complex in their structure. Most of the packaging films that are used for shrink and stretch wrapping are from the polyolefin range. These are materials produced from oil based chemicals by what is called a polymerization process, which basically means getting the right molecules and atoms to club together in a way that is required Shrink Pack 342 or desirable for a particular application. The most common plastic materials are polyethylene, polypropylene and poly vinyl chloride. Polypropylene is comparatively less used in shrink and stretch wrapping, because it is slightly harder than the other commonly used materials. It has a higher melting temperature and is less stable when shrinking. However, many over-wrapping machines use polypropylene and some can be put through a shrink tunnel to give a slight tightening effect. PVC is a dense material. As most polymers are sold by weight and there has been ecological pressure in Europe and America against its use, sometime use of PVC is restricted.

However, it is still considered to be a common material in India, when clarity is an important selection criterion, particularly for consumer packaging. Polyethylene is the most commonly used material for shrink and stretch wrapping because it is relatively cheap and can be produced in a range of different densities and modified with additives to perform many functions. The vast majority of shrink film is LDPE and some of the more sophisticated films have blends of LLDPE as well. Sometimes a little quantity of HDPE material is also added. For selection of plastic material, besides type of plastics, the yield of the film is also important to be considered from the economy point of view. The yield means the area obtained or number of square meters of film converted from a kilogram of material of a given thickness or gauge. The gauge may be expressed in micron (0.001 mm), mil (an American terms for thousandths of an inch i.e. 0.001 inch) or simply gauge, which is the old British system where 100 gauge equals one thousandth of an inch. The co-relation of both the systems of measurement of thickness is 25 micron (or 0.025 mm) equals 100 gauge (or 0.001 inch). For shrink film, the next important factors considered are the shrinkage and the slip of the film.

Shrinkage

Shrinkage means the percentage shrink in the machine direction, i.e. along the reel of the film, and also in the transverse direction, i.e. across the reel of the film. The slip can be of different types – high, medium or low depending upon how much slippery property in the film is required from the operational point of view. Usually, low slip is desirable. For shrink wrapping small packs at high speed, particularly for consumer products or display purposes, PVC or specially modified Polyolefin may be used. The “high shrink films” are crystal clear but generally expensive. For stretch wrapping, majority of films are modified linear low density polyethylene (LLDPE), often three-layer extrusion with “tackifier” added to make them sticky on either one or both sides. Some PVC films are also used.

Important Material Properties of Shrink / Stretch Film Low Melt Flow Index (MFI) for PE film (e.g. 0.1 to 0.6) indicates high melt viscosity, which in turn depends upon the fact that the material is composed mainly of long-chain molecules i.e. has a higher molecular weight. Therefore, low MFI of LDPE gives a logical guarantee for high film strength, often a prime requirement for wrapping goods or pallet loads. As MFI has direct relevance to orientation, stretch properties, strength, etc., shrink / stretch films are divided into 3 MFI classes:

- MFI < 0.6 : For heavy goods and pallet loads
- 0.6 < MFI < 1.0 : For lighter packages where high transparency is valued more than the maximum strength
- MFI > 1.0 : For applications, where strength is of minor importance; used for textiles and such products where a weak shrinkage force is desirable.

Performance Comparison of Shrink Films

Film Type	Advantage	Disadvantages
Polyethylene (low density)	Strong heat seals Low temperature shrink	• Narrow shrink temperature • Low stiffness • Poor optical property • Sealing wire contamination
Polypropylene	• Good optical appearance • High stiffness	• High shrink temperature • High shrink force, not suitable for delicate or fragile product

	• High shrink force • No heat sealing fumes • Good durability	• Brittle seals • High sealing temperature
Co-polymers	• Strong heat seals • Good optical appearance • High shrink force • No heat sealing vapours	• High shrink force, not suitable for fragile products • Higher shrink temperature • Higher heat seal temperature 4) Lower film slip-may give machine problems
Poly Vinyl	• Lowest shrink temperature • Wide shrink temperature range • Excellent optical appearance • Controlled stiffness by plasticizer content control • Lowest shrink force for wrapping fragile products	1) Weakest heat seals Chloride 2) Least durable after plasticizer loss 3) Toxic and corrosive gas emission 4) Low shrink force inhibits use as a multiple –unit bundling film 5) Low film slip causes machine wrapping difficulties
Multilayer Co-extrusion	• Excellent optical appearance • Good machineability • Low shrink temperature	In co-extruded films, one ply compensates for the deficiencies of the other. As a result, they are superior films with no significant performance shortcomings. 2) The wide variability in layer composition and number of layer makes performance analysis difficult.



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AQUATIC POLLUTANTS: CHALLENGES FOR AQUACULTURE AND BIODIVERSITY

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Abstract

The sustainability and diversity of aquaculture systems are seriously threatened by aquatic contaminants. By altering the chemistry of the water, stressing aquatic life, and lowering dissolved oxygen, a variety of contaminants from industrial, residential, and agricultural sources upset the ecosystem. The food webs may be impacted by immune suppression and mortality brought on by prolonged exposure. Present article explores the major aquatic pollutants, their sources, impact on aquatic organisms, financial ramifications, and some mitigation measures.

Introduction

Any material or organism that contaminates water and has the potential to harm living organisms and the environment is referred to be an aquatic pollutant. Numerous human activities result in the release of different contaminants into aquatic ecosystems, endangering the health of organisms and degrading the environment by making water bodies unsuitable (Ekubo and Abowel, 2011). Pathogens, radioactive materials, heat, sediments, inorganic and organic pollutants, and toxic metals are a few examples of these pollutants. Point sources and non-point sources are the two primary sources of water contamination. Concentrated pollution coming from a single, distinguishable source is referred to as a point source (Kehinde, 2022). Point sources include things like septic tank or sanitary sewage overflows, industrial production, runoff from mining operations, wastewater treatment facilities, and unintentional spills. On the other hand, effluence that originates from more than one isolated source is implied by effluence from non-point sources (Sadauki *et al.*, 2024).

Agricultural runoff, nitrogen compounds from fertilised land, and polluted storm water that is carried off from parking lots, roads, and highways and referred to as urban runoff are examples of non-point sources. Through absorption of polluted sediments, bioaccumulation through the food chain, and direct contact with contaminated water, aquatic organisms are continuously exposed to these pollutants (Franzellitti *et al.*, 2019). Aquatic life, ecological health, and the sustainability of aquaculture industries can all be significantly impacted by these pollutants. Reduced dissolved oxygen, altered water pH, and the introduction of harmful chemicals are just a few of the ways pollutants can impact aquatic life. Thus the aim of current article is to explore different types of aquatic pollutants and their influence on aquatic life. It further proposes some mitigation strategies to ensure aquaculture resilience.

Major Types of Aquatic Pollutants:

The different types of aquatic pollutants include; Industrial pollutants (heavy metals, toxic wastes, petroleum products), Agricultural pollutants (pesticides, herbicides, fertilizers, livestock waste), Domestic pollutants (sewage, detergents, plastics), Pharmaceutical pollutants and some other pollutants like sediments, thermal pollutants and radioactive substances. Broadly classified, chemical, biological, and physical pollutants are the different forms of aquatic pollutants. According to (Weldeslassie *et al.* (2018), chemical pollutants include the discharge of dangerous materials into water bodies, such as pesticides, fertilisers, heavy metals, and medications. Because fertilisers and pesticides used in farming frequently wash into neighbouring rivers and lakes during rainfall, agricultural runoff is a significant source of chemical contamination. Substances that change the physical properties of water, affecting its inherent qualities and possibly endangering aquatic life, are known as physical aquatic pollutants. These contaminants include discharges, immiscible liquids, and suspended solids. Additionally, it covers the issues that aquatic alien species pose to native species (Olenin *et al.*, 2007). In addition to this, there are some emerging pollutants like microplastic and Nanomaterials that alter the biodiversity of aquatic ecosystem.

Impact of Aquatic Pollutants on Biodiversity and Aquaculture Systems:

Pollutants can harm the environment directly through primary damage or indirectly through small disruptions to the delicate equilibrium of the biological food web that are only noticeable over extended periods of time (Ghani, 2015). Sewage discharge causes the aquatic system to become eutrophic, which deoxygenates the water and increases the mortality rate of

aquatic organisms and submerged aquatic vegetation. Problems and asphyxia in respiratory physiology and mucus production caused by suspended particles make fish more vulnerable to diseases caused by aquatic pathogens.

The reproductive function of aquatic animals is suppressed and the death rate is increased by metals and agrochemical chemicals (Kime, 1995). Heavy metal pollution has a major effect on the physiology of many aquatic animals, changes the hemato-biochemical parameter, causes genetic anomalies, and severely reduces fish reproductive capacity (Khushbu *et al.*, 2022). Amphipod cuticles, fish gills, and other delicate aquatic organs absorb metals that are dissolved in the environment (Dehghani *et al.*, 2022). Heavy metals are strong neuro-toxicants that have been connected to deformities in fish populations. Moreover, it actively accumulates in the bodies of microscopic creatures with a large surface area, such as phytoplankton and zooplankton (El-Metwally *et al.*, 2022). By inducing oxidative stress, pesticides can have cellular effects on aquatic organisms by altering the chemical and physical makeup of cell, harm the lipid membrane, and interfere with cell signalling pathways (Saha and Dutta, 2024). In addition to potential long-term and developmental consequences, pesticide exposure may also affect acute toxicity.

Pesticide residues can raise the levels of ammonium, nitrite, nitrate, and sulphate in aquatic systems, endangering both human health and ecosystem (AbuQamar *et al.*, 2024). Thermal pollution causes the water surrounding temperature to fluctuate and lowers the amount of dissolved oxygen in the water column, which leads to the death of delicate and small aquatic life. Because oil spills introduce contaminants, change ecosystems, and disturb food webs, they seriously impair aquatic biodiversity. The damage is estimated to increase by approximately US\$0.718 million for every 1% increase in spill size (Alló and Loureiro, 2013). The presence of microplastics in aquatic habitats is detrimental to organism health. Low-density microplastics remain at the water surface and are eaten by filter-feeding invertebrates and carnivorous fish (Zhu *et al.*, 2022). On the other hand, high-density microplastics float in the water column and be eaten by omnivorous fish (Zhang *et al.*, 2017). Additionally, since heavy metals are not eliminated from water, they build up in water reservoirs and then make their way into the food chain, giving them high ecological significance (Loska and Wiechuła, 2003). In addition to this, aquatic pollutants result in economic losses as they pose risk to food security and food safety and impact the recreational fishing industries (Diner *et al.*, 2024).

Mitigation Strategies and Recommendations:

A variety of tactics are used to mitigate aquatic pollution, ranging from keeping contaminants out of waterways, to cleaning them up after they have already been discharged. The effluent coming from industrial and municipal sources should be improved by used technologies like bio filtration and by using membrane filters. Non- point source runoff can be reduced by using sustainable farming methods, such as buffer zones close to water sources, organic farming, and restricted fertiliser use. Long-term aquatic environment protection also depends on promoting circular economy models and promoting the reduction, reuse, and recycling of materials, particularly plastics. Metals and pesticides should be removed from aquatic environments using bioremediation techniques. Pollutant discharge into aquatic bodies can be considerably decreased by enforcing real-time monitoring systems. Protecting aquatic environments requires efficient management of wastewater discharge, including regulation and monitoring. Strict water quality standards should be set by regulatory frameworks, and regular reporting and monitoring should be used to ensure compliance. Additionally, community participation in monitoring initiatives and public awareness campaigns can strengthen the efficacy of legislative actions and advance environmentally friendly wastewater treatment techniques. The effluent coming from industrial and municipal sources should be improved by used technologies like bio filtration and by using membrane filters.

Conclusion

Aquaculture production, aquatic biodiversity and ecological stability are all endangered by aquatic pollution. The accumulation of these contaminants over time has a significant impact on ecosystem, human health and food systems. At the scientific, policy, and community levels, swift and cooperative action is required to minimise harm and protect aquatic species. The restoration of ecological balance and the resilience of aquatic habitats can be achieved by placing a strong emphasis on pollution control, ecosystem-based management, and sustainable aquaculture methods.

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GERIATRIC NUTRITION: A TECHNICAL PERSPECTIVE ON NUTRITIONAL NEEDS OF THE ELDERLY

Article ID: AG-VO5-I06-102**Bratati Das¹, AA Joshi² and V.S Pawar²**

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Abstract

Geriatric nutrition is a specialized field focusing on the dietary needs and challenges of older adults. As individuals age, physiological changes such as reduced metabolic rate, decreased appetite, and altered nutrient absorption can impact nutritional status. Additionally, chronic conditions like diabetes, hypertension, and cognitive decline further complicate dietary requirements. Key nutritional considerations for the elderly include adequate protein intake to prevent sarcopenia, ensuring sufficient caloric intake to maintain energy balance, and addressing micronutrient deficiencies, particularly in vitamin D, B12, and calcium. Dietary patterns such as the Mediterranean-DASH Diet Intervention for Neurodegenerative Delay (MIND) diet have shown promise in reducing cognitive decline and promoting brain health. Furthermore, managing hydration and addressing issues like dysphagia are crucial for maintaining overall health in geriatric populations. Early identification and intervention in nutritional deficiencies are vital to prevent complications like malnutrition, frailty, and functional decline. Healthcare providers play a pivotal role in assessing and addressing the unique nutritional needs of older adults to enhance their quality of life and longevity.

Keywords: geriatric nutrition, aging, sarcopenia, malnutrition, MIND diet, protein intake, micronutrients, hydration, dysphagia, cognitive decline, dietary patterns, elderly health

Introduction

In older adults, satisfaction with eating is a crucial component of overall quality of life. Many individuals over 65 experience partial or complete tooth loss, leading to diminished chewing efficiency. This reduction in masticatory function often results in dietary modifications, which can significantly affect health outcomes. Restoring lost chewing ability in edentulous seniors presents a challenge for dental professionals. However, other factors also play a role in the nutritional status of older adults. Age-related health conditions, socioeconomic status, and dietary habits all influence food choices and nutritional intake.

By understanding the nutritional needs, signs of malnutrition, and environmental influences on food selection, dentists can identify patients at risk of malnutrition and provide appropriate dietary guidance. Since each patient's oral health and nutritional requirements are unique, personalized recommendations are essential. This article explores the connection between dental health and nutrition in the elderly population.

Process of Ageing

Ageing is a natural biological process that commences at conception and continues throughout life, culminating only with death. Individuals experience ageing at varying rates, influenced by factors such as genetics, race, and gender. While heredity and proper nutrition can decelerate the ageing process, enabling individuals to maintain physical and mental vitality into their eighties, the primary objective of nutritional care should be to assist older adults in achieving healthy, purposeful, and independent living.

A prominent theory explaining ageing is the free radical theory, which posits that the continuous formation of free radicals—highly reactive molecules resulting from oxygen exposure and environmental factors—leads to cellular damage. These free radicals can alter the structure of proteins, lipids, carbohydrates, and DNA, contributing to the physiological changes associated with ageing.

Tissue damage caused by free radicals and pro-oxidant radicals, such as superoxide, peroxide, and hydroxyl radicals, underpins inflammatory and degenerative changes. Endogenous antioxidants, including superoxide dismutase (SOD), catalase (CAT), and glutathione peroxidase (GPX), work synergistically with glutathione (GSH) and NADPH to neutralize these harmful radicals. However, with age and in certain diseases, these antioxidant defenses diminish, leading to excessive utilization of vitamins A, C, and E, resulting in deficiencies.

The ageing process induces physiological, psychological, and immunological changes that influence nutritional status. Free radicals are believed to cause degenerative changes, potentially leading to conditions such as cancer, cataract formation, atherosclerotic plaques, arthritis, and Parkinson's disease.

Factors such as the inability to prepare food, decreased purchasing capacity, and psychosocial issues negatively impact the health and nutritional status of the elderly. Reduced physical activity and dental problems can lead to decreased food intake and poor nutrient absorption. Additionally, changes in organ function associated with ageing may further influence nutritional status.

Changes in organ function with ageing changes aging that may influence nutrient requirements.

Organ function	Changes	Effect on nutrition
Taste and smell	• Decreased taste buds and papillae on tongue. • Decrease in taste and olfactory nerve endings.	• Loss of ability to detect salt and sweet. • Decreased palatability causing poor food intake. • Decreased sensory stimulation that may impair metabolic processes.
Salivary glands	• Decrease in salivary secretion causes feeling of dry mouth, xerostomia.	• Difficulty in chewing and swallowing make them avoid certain foods particularly crunchy, dry and sticky foods.
Teeth	• Loss of teeth and wearing dentures	• Decreased consumption of meats and fresh fruits and vegetables particularly which are hard (carrot) and have lot of seeds (guava). In turn this can result in inadequate intake of energy, iron and vitamins particularly vitamin C, folate and Beta-carotene.
Gastric function and emptying	• Decreased secretion of hydro-chloric acid, intrinsic factor and pepsin. • Above 60 years of age rapid rate of emptying of liquids.	• Decreased bioavailability of minerals, vitamins and proteins. • Decreased absorption of protein bound vitamin B12 and folate.
Small intestine	• Increased proximal small bowel pH and	• Increase in bacterial folate synthesis to counteract malabsorption.

	- bacterial over growth in bowel • Decreased calcium absorption • Decreased secretion of lactase • Constipation-prolonged rectosigmoid transit	• Poor vitamin D nutriture • Can be a risk factor for developing osteoporosis
Liver and Biliary function	• Decreased size and blood flow • Minor structural and bio-chemical changes • Gall bladder becomes sluggish in releasing bile • Activity of drug metabolising enzymes reduced.	• Rate of albumin synthesis may be decreased • Susceptible to gallstones • Drug dosages may need to be lowered.
Metabolic function	• Impaired glucose tolerance • Decreased metabolic rate due to changes in body composition and reduction in physical activity. • Body protein level decreases	• Requires dietary modifications, exercise and oral pharmacologic agents. • Requirement of energy decreases. • Activity decreases
Neurologic function	• Confusional states	• Decreased synthesis of serotonin: Carnitine derived from the amino acids lysine and methionine may be effective in slowing the mental deterioration in Alzheimer's disease. • Carotenoids seem to play a protective role related to ageing and cognitive function.
Immuno competence	• Declines with age	• Supplementation with vitamin E, zinc and polyunsaturated fatty acid can be increased.
Ophthalmic function	• Opacity of eye lens	• Increased requirement of antioxidant
Cardiovascular function	• Blood vessels become less elastic and total peripheral resistance	• Prevalence of hypertension, modification of diet accordingly.



	increases.	
Renal function	• Glomerular filtration rate can diminish as much as 60 per cent, changes in fluid and acid base balance.	• Protein, sodium and potassium nutrition may be affected.
Psychological factors	• Depression	• Can affect appetite, digestion, energy level, weight and well-being.

Essential, nutrients for seniors, Dietary recommendation for elderly Balanced meal planning

Essential Nutrients for Seniors

As individuals age, their nutritional needs evolve, necessitating a balanced diet rich in specific nutrients to support overall health and well-being. This section explores the importance of protein, fiber, vitamins, and minerals for older adults.

Protein

Protein is vital for maintaining muscle mass, supporting the immune system, and promoting wound healing. Older adults may require higher amounts of protein to preserve muscle mass and strength, which can decline with age. Incorporating lean meats, fish, eggs, dairy products, legumes, and nuts into the diet can help seniors meet their daily protein needs. It's advisable to spread protein intake throughout the day to maximize absorption and utilization by the body.

Protein Sources and Content:

Food Item	Protein (g) per Serving
Chicken Breast (3 oz)	26
Salmon (3 oz)	19
Eggs (1 large)	6
Almonds (1 oz)	6

Fiber

Fiber plays a crucial role in digestive health, helps maintain a healthy weight, and can lower the risk of heart disease and type 2 diabetes. Older adults should aim to include a variety of fiber-rich foods in their daily diet, such as whole grains, fruits, vegetables, and legumes.

Fiber Sources and Content:

Food Item	Fiber (g) per Serving
Whole Wheat Bread (1 slice)	2
Apple (1 medium)	4
Black Beans (1/2 cup)	7
Broccoli (1 cup)	5

Vitamins

Vitamins are essential for overall health and well-being. For older adults, certain vitamins like B12, which supports nerve function, and D, which aids in calcium absorption for bone health, are especially important. Older individuals should try to get these vitamins from a balanced diet, but in some cases, supplementation may be necessary.

Vitamin Sources:

Vitamin	Food Sources
Vitamin B12	Fish, poultry, meat, eggs, dairy
Vitamin D	Fatty fish, fortified dairy products, egg yolks

Minerals

Minerals like calcium and potassium are also vital for elderly nutritional needs. Calcium is essential for maintaining bone health, while potassium can help regulate blood pressure. Dairy products, leafy green vegetables, and fruits like bananas and oranges are excellent sources of these minerals.

Mineral Sources:

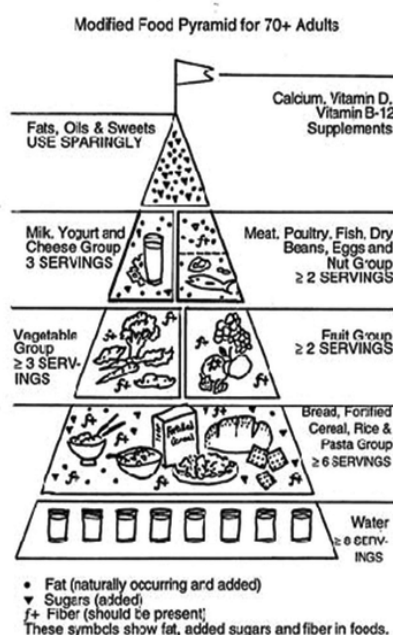
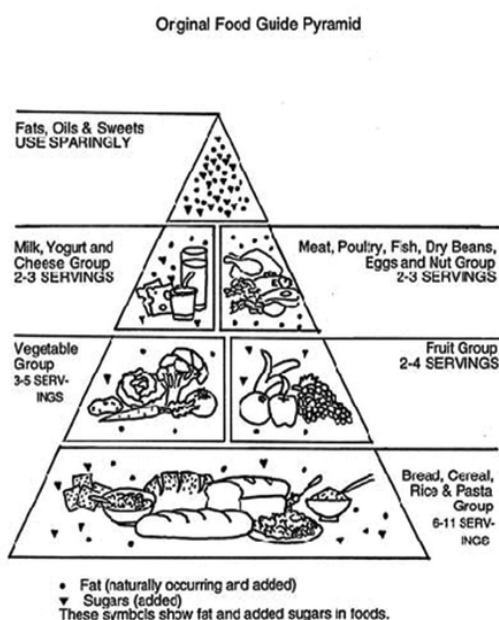
Mineral	Food Sources
Calcium	Milk, yogurt, cheese, leafy green vegetables
Potassium	Bananas, oranges, potatoes, spinach

It's important to note that each individual's nutritional needs can vary, and it's always best to consult with a healthcare professional or dietitian to determine the most appropriate diet. Ensuring a balanced intake of these essential nutrients can significantly contribute to the health and wellness of seniors.

5.1 Daily nutrient Recommendations for the Elderly, ICMR 2024

Nutrient	Men (≥60 years)	Women (≥60 years)
Energy	1700 kcal	1500 kcal
Protein	54.0 g	45.7 g
Dietary Fibre	32 g	25 g
Vitamin A	1000 µg	840 µg
Thiamine (B1)	1.4 mg	1.4 mg
Riboflavin (B2)	2.0 mg	1.9 mg
Niacin	12 mg	9 mg
Vitamin C	80 mg	65 mg
Vitamin B6	1.9 mg	1.9 mg
Folate	300 µg	200 µg
Vitamin B12	2.2 µg	2.2 µg
Vitamin D	800 IU	800 IU
Calcium	1200 mg	1200 mg
Magnesium	440 mg	370 mg
Iron	19 mg	19 mg
Zinc	17 mg	13.2 mg
Iodine	150 µg	150 µg

MODIFIED FOOD PYRAMID FOR ELDERLY



Modification of diet to suit the needs of old age

As individuals age, various physical, physiological, and psychological changes occur, necessitating specific dietary modifications to maintain health and well-being. The following adjustments are recommended:

1. **Dental Health Considerations:** Due to potential tooth loss or dental issues, it's advisable to include soft-textured foods that are easy to chew, such as cooked vegetables, tender meats, and well-cooked grains. journals.lww.com
2. **Digestive Efficiency:** With a decrease in the production of digestive enzymes, it's beneficial to consume easily digestible foods like soups, stews, and pureed dishes to facilitate nutrient absorption.
3. **Fat Intake:** Limiting the intake of saturated fats and avoiding foods high in unhealthy fats can help prevent obesity and reduce the risk of cardiovascular diseases.
4. **Energy-Dense Foods:** Limiting the consumption of energy-rich foods such as sweets, fried items, and starchy foods can help manage weight and prevent metabolic issues.
5. **Calcium-Rich Foods:** Incorporating foods high in calcium, like dairy products and leafy greens, supports bone health and helps mitigate the effects of osteoporosis. cubua.pressbooks.pub
6. **Fruits and Vegetables:** Including a variety of fresh fruits, vegetables, and green leafy vegetables provides essential vitamins, minerals, fiber, and antioxidants. These can be consumed as juices, purees, soups, or salads to enhance nutrient intake.
7. **Caffeine and Stimulants:** Limiting the intake of coffee, tea, and carbonated beverages can help prevent insomnia and promote better sleep quality.
8. **Meal Frequency:** Opting for smaller, more frequent meals throughout the day can aid in digestion and ensure adequate nutrient intake.
9. **Hydration:** Consuming an adequate amount of fluids is essential to prevent dehydration and support overall health.
10. **Salt Intake:** Reducing salt consumption can help manage blood pressure and reduce the risk of cardiovascular issues.

Ensuring a diet that is nutritionally adequate, well-balanced, and tailored to the specific needs of older adults is crucial for maintaining health and quality of life.

Nutritional Screening and Assessment

Routine screening using tools like:

1. MNA (Mini Nutritional Assessment)

The Mini Nutritional Assessment (MNA) is a widely used, validated screening tool designed to evaluate the nutritional status of elderly individuals, particularly those over the age of 65. Developed in the 1990s by Vellas and colleagues, the MNA helps identify malnutrition and the risk of malnutrition before significant weight loss or other clinical signs appear. It consists of two forms: the MNA-Short Form (MNA-SF), which includes six basic questions, and the full MNA, comprising 18 items that assess dietary intake, anthropometry, lifestyle, and subjective health status. The tool is non-invasive, cost-effective, and can be administered by healthcare professionals or caregivers in community and clinical settings. A score of 12–14 on the MNA-SF indicates normal nutritional status, 8–11 suggests a risk of malnutrition, and 0–7 reflects malnutrition. The MNA has shown high sensitivity (96%) and specificity (98%) in identifying nutritional issues and is strongly correlated with clinical outcomes such as increased morbidity, hospitalizations, and mortality in older adults (Guigoz, 2006; Kaiser et al., 2010). Its ease of use and reliability make it a cornerstone of geriatric nutritional assessment worldwide.

2. MUST (Malnutrition Universal Screening Tool)

The Malnutrition Universal Screening Tool (MUST) is a validated, evidence-based screening instrument developed by the British Association for Parenteral and Enteral Nutrition (BAPEN) to identify adults at risk of malnutrition in hospital, community, and care home settings. It is a simple five-step tool that assesses body mass index (BMI), unintentional weight loss, and the presence of acute disease with no nutritional intake for more than five days. Each parameter is scored, and the total score categorizes individuals into low (score 0), medium (score 1), or high risk (score ≥ 2) of malnutrition. MUST is widely recognized for its practicality and reliability and is recommended in clinical guidelines across the UK and Europe for routine nutritional screening. Studies have shown that MUST is effective in predicting adverse outcomes such as increased length of hospital stay, complications, and mortality in both community and clinical populations (Stratton et al., 2004; Elia, 2003). Its widespread adoption has contributed significantly to early identification and intervention for malnutrition, thereby improving patient outcomes and reducing healthcare costs.

3 . SNAQ (Short Nutritional Assessment Questionnaire)

The Short Nutritional Assessment Questionnaire (SNAQ) is a quick and practical screening tool developed to identify individuals at risk of malnutrition, particularly in hospitalized patients and elderly populations. Designed to be completed in less than five minutes, SNAQ consists of three to four simple questions that assess unintentional weight loss, decreased appetite, and the use of supplemental feeding such as nutritional drinks or tube feeding. Each response is scored, and a total score of 2 or more indicates a risk of malnutrition, prompting further nutritional assessment or intervention. The tool has been validated in various clinical settings and has demonstrated good sensitivity and specificity for predicting weight loss and poor clinical outcomes in hospitalized patients (Kruizenga et al., 2005). Its brevity, ease of use, and strong predictive value make SNAQ particularly useful in busy healthcare environments where rapid screening is essential to ensure early nutritional support and improve recovery outcomes. can help in early detection of malnutrition and undernutrition in older adults (Kondrup et al., 2003).

Dietary Tips for elderly

As we age, our nutritional needs evolve, requiring thoughtful dietary choices to maintain strength, immunity, and metabolic health. For seniors in India, a balanced diet should emphasize easily digestible, fiber-rich foods such as whole grains (e.g., dalia, brown rice, and millets), along with seasonal fruits and vegetables like papaya, banana, and guava. These choices aid digestion and are rich in antioxidants.

Incorporating calcium-rich foods like low-fat curd, paneer, and ragi is essential for bone health. Adequate protein intake is crucial for maintaining muscle mass; options include soft-cooked dals, legumes, eggs, or curd. Hydration is often overlooked in older adults, so it's important to ensure they drink enough water, coconut water, and light herbal teas.

Reducing consumption of salt, sugar, and greasy foods can help manage age-related issues like hypertension and diabetes. Eating smaller, more frequent meals tends to be easier on the stomach than having large, infrequent ones. Additionally, spices like turmeric, ajwain, and jeera not only enhance flavor but also aid digestion and reduce inflammation. These dietary recommendations align with the guidelines from the National Institute of Nutrition (ICMR-NIN) and the Ministry of Health and Family Welfare (MoHFW), making them both culturally relevant and medically sound.

Nutrition related problems of old age

As individuals age, physiological changes often lead to nutritional challenges among the elderly in India. Common issues include reduced appetite, dental problems, and impaired digestion, resulting in insufficient nutrient intake. Deficiencies in micronutrients such as calcium, vitamin D, vitamin B12, and iron are prevalent, contributing to conditions like osteoporosis, anemia, and general weakness. Chronic illnesses such as diabetes, hypertension, arthritis, and gastrointestinal disorders further complicate nutrient absorption and dietary habits. Socioeconomic factors, including living alone, limited income, and decreased mobility, also affect access to nutritious food. Additionally, dental issues like tooth loss can lead to the avoidance of fiber-rich foods, exacerbating problems like constipation and malnutrition. Psychological conditions such as depression and dementia can disrupt regular eating patterns. To address these concerns, the ICMR-NIN and FSSAI recommend an integrated approach that includes easily chewable, nutrient-dense meals, and fortified foods. Personalized diets tailored to individual health conditions, along with regular nutritional assessments, are essential components of geriatric care in India.

Nutritional Requirements for the Elderly in India

The ICMR Expert Group on Nutrient Requirements has updated the Recommended Dietary Allowances (RDA) for Indians, aligning with international guidelines from FAO/WHO/UNU. The 2020 recommendations introduce three key dietary reference values: Estimated Average Requirement (EAR), RDA, and Tolerable Upper Intake Level (TUL). While EAR represents the average requirement for a population, RDA is designed to meet the nutritional needs of nearly all healthy individuals in a specific age, gender, and physiological group. TUL indicates the maximum daily intake unlikely to cause adverse health effects. These values were derived using a factorial approach, considering factors like energy expenditure and nutrient bioavailability, and adjusting for age, gender, and physiological status.

For the elderly population (≥ 60 years), the ICMR-2020 guidelines suggest a decrease in energy intake—by 100 kcal per decade for men and 70 kcal for women—due to reduced physical activity. Conversely, vitamin D intake is recommended to be higher to counteract age-related bone loss and prevalent deficiencies. These adjustments are based on the understanding that age-related physiological and sensory changes may affect nutrient requirements in older adults.

Therefore, more evidence-based nutrient requirement recommendations need to be derived and adopted for the elderly in India. [pmc.ncbi.nlm.nih.gov](https://pubmed.ncbi.nlm.nih.gov)

Conclusion

Geriatric nutrition is pivotal in enhancing the health and quality of life of older adults. Aging brings about physiological changes that can lead to malnutrition, frailty, sarcopenia, and other geriatric syndromes. Addressing these challenges requires personalized nutritional strategies that consider individual needs and conditions. Effective interventions include adequate protein intake, adherence to balanced diets like the Mediterranean diet, and the use of oral nutritional supplements when necessary. Additionally, addressing issues such as dysphagia and sensory impairments is crucial to ensure proper nutrition. Technological advancements offer promising tools for monitoring and managing nutritional status in the elderly.

In conclusion, a comprehensive approach to geriatric nutrition, encompassing early detection, personalized care, and ongoing support, is essential for promoting healthy aging and preventing nutrition-related complications.

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BASMATI (INDIA-US BASMATI RICE DISPUTE)–A SUCCESSFUL CASE STUDY ON IP PROTECTION & MANAGEMENT IN INDIA

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Introduction

Rice is an important aspect of life in the Southeast and other parts of Asia. For centuries, it has been the cornerstone of their food and culture. Basmati has been grown in the foothills of the Himalayas for thousands of years. It is also grown in Pakistan, Nepal, Indonesia, and Sri Lanka. Basmati describes a variety of aromatic, long-slender rice grains. It has a distinct fragrance, texture, taste, and aroma. The flavor and aroma have been developed through selective breeding for thousands of years. It is common knowledge that what Champagne is to France, Basmati is to Subcontinent (Pakistan and India). There are 34 varieties of Basmati registered under the seeds Act, 1966. As per the (Indian) Geographical Indications of Goods (Registration and Protection) Act, 1999 a geographical indication (GI) tag is granted to protect the unique qualities of a product that are specific to its geographical origin. Articles 22 to 24 of Part II Section III of the TRIPS prescribe minimum standards of protection to the geographical indications that WTO members must provide. Falsification of a GI will carry a penalty with imprisonment.

The Issue

In late 1997, an American company RiceTec Inc was granted a patent by the US patent office to call the aromatic rice grown outside India 'Basmati'. Inc had been trying to enter the international Basmati market with brands liRiceTecke 'Kasmati' and 'Texmati' described as Basmati-type rice with minimal success. This has grave repercussions for India and Pakistan because not only will India lose out on the 45,000 tonne US import market, which forms 10

percent of the total Basmati exports, but also its position in crucial markets like the European Union, the United Kingdom, Middle East, and West Asia.

In addition, the patent on Basmati is believed to be a violation of the fundamental fact that the long grain aromatic rice is grown only in Punjab, Haryana, and Uttar Pradesh is called Basmati. Economic Times described it as "Patenting Basmati in the US is like snatching away our history and culture."

The Rice Patent

RiceTec Inc was issued Patent number 5665484 on Basmati rice lines and grains on September 2, 1997. In abstract, "the invention relates to novel rice lines and plants and grains of these lines. The invention also relates to a novel means for determining the cooking and starch properties of rice grains and its use in identifying desirable rice lines.

The first aspect of the invention relates to novel rice lines whose plants are semi-dwarf in stature, substantially photoperiod insensitive and high yielding, and produce rice grains having characteristics similar or superior to those of good quality Basmati rice.

The second aspect of the invention relates to novel rice lines produced from novel rice lines. The invention provides a method for breeding these novel lines.

The third aspect relates to the finding that the starch index (SI) of a rice grain can predict the grain's cooking and starch properties, to a method based thereon for identifying grains that can be cooked to the firmness of traditional Basmati rice preparations, and to the use of this method in selecting desirable segregants in rice breeding programs."

The Government of India's response to the Patent

In an official release, the Government of India reacted immediately after learning of the Basmati patent issued to RiceTec Inc., stating that it would approach the US patent office and urge them to re-examine the patent to a United States firm to grow and sell rice under the Basmati brand name to protect India's interests, particularly those of growers and exporters.

The Govt. of India formed a high-level inter-ministerial group comprising representatives of the ministries and departments of commerce, industry, external affairs, Council for scientific and industrial research CSIR Agriculture, Bio-technology, All India Rice Exporters Association (AIREA), APEDA, Indian Council of Agricultural Research (ICAR) were mobilized to begin an in-depth examination of the case.



India Challenged three Claims (15, 16, and 17) of Rice Tec's patent. These claims were related to grain quality such as in cooking and aroma of basmati grain. Rice Tec however withdraw 4 claims (4,15,16,17) out of 20 including the three claims objected by India. APEDA through the Government of India reported to Supreme Court that they are not interested to contest the matter any further as the Rice Exporters' interests have been protected by the withdrawal of four claims. Further USPTO went on to strike down Claims 1-7, 10, 14-20. of Rice Tec patent and now patent has the validity on claim nos. 8, 9, 11 12, and 15, only, after amendments

We have won the Basmati biopiracy battle, though the war for the defense of farmers' rights, indigenous knowledge, and biodiversity still needs to be won. And this partial victory has been based more on citizens' actions than government action. As a result of a worldwide citizen campaign against Rice Tec Basmati patents, on Aug 14th, 2001 the U.S. Patent and Trademark Office struck down large sections of the Basmati patent. The generic title of the RiceTec patent No. 5665484, which earlier referred to Basmati rice lines. The sweeping and false claims of Rice Tec having 'invented', traits of rice seeds and plants including plant height, grain length, and aroma which are characteristics found in our traditional Basmati varieties.

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COCONUT BASED MULTI-STOREY CROPPING SYSTEM IN HORTICULTURAL CROPS

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Abstract

Coconut based multi-storey cropping systems with other horticultural crops offer immense potential improving the farm income. The crops of different heights and compatible nature are selected for grow along with the coconut palms. In multi storied cropping system two or more crops of different heights are grown simultaneously on a piece of land in a certain period. A multi storey cropping system accommodates crops of different heights, canopy patterns and root system to maximize use of sunlight, nutrient, sustainable land use and maintain an ecological balance. In this system of cropping, the possibility of more efficient use of resources like sunlight, water, soil and nutrient is leading to increased biological diversity, more crops per unit area and sustainability of production. Coconut based multi storey cropping system improve the production coconut as well as companion crops through circular loops of nutrient recycling. Multi-storey cropp in coconut need to be popularized in large scale plantations with a perspective of food security, productivity, crop diversification, resource utilization, economic viability etc.

keywords: coconut, multi-storey, cropping system, canopy pattern, ecological balance

Introduction

Coconut is eulogized as the 'Kalpavriksha', the "Tree of life", due to its multifarious utilization as fuel, medicine, timber and other utility purposes of different parts from root to leaves, from tender water to outer husk, etc. Coconut is the most important plantation crop grown in coastal area and other area of India. It provides food and livelihood security to millions of people in the country. Normally, coconuts planted at a spacing of 8m x 8m to 10m x 10m offer

good opportunities for an effective utilization of the interspace between the palms. Since the maximum effective root zones is 2 m, only 12.6 to 19.6 % of the total area is effectively utilized for a single palm leaving 80.4 to 87.4 % available for other crops. However, with the traditional cropping system, farmers are finding it difficult to produce adequate food to feed their families. The only way to convert these holdings into profit-making ones is through the intensive use of land through diversification of crops. Thus an integrated system with several crop combinations to maximize land use and generate additional income. The practice of multiple cropping permits crop diversification to spread out the risk to more crops thus eliminating the dependence of income on a single crop.

Coconut as a monocrop is not efficient in sustaining the farm income; however the coconut based cropping systems with suitable other horticultural crops offer immense potential in improving farm income. More than 100 different crops and systems have been identified across the globe that be grown as intercrops in coconut plantations. The multi-storey cropping in coconut lands depends the age of the coconut palms, water availability, shade of understory, soil characteristics, the slope of land, labor availability, market demand, economic status of the grower, and social characteristics.

Coconut based multi-storey cropping system mainly focus on growing of different horticultural crops targeting maximum utilization of resources in the unit area. The selection of crops is done such a v to avoid competition among the crops and ensuring optimal use of resources. The crops of differ heights and compatible nature are selected for growing along with the coconut palms. There are differ vegetable crops, cut and loose flowers, indigenous and exotic fruit crops, medicinal plants, fodder crop spices etc which can be part of the multi-storey cropping system.

Coconut plantations are ideal for multi-storey cropping production systems across stages of growth a development. The crop is widely spaced one and has peculiar morphological characters giving am space for taking up other crops. The spacing followed in coconut plantations are generally 7.5 m between rows and 7.5 m between plants offering wider interspaces in the gardens. The soil area effectively utilized by coconut palms in plantations having 7.5 m spacing is only 23 percent and the effective root zone spread around the base of the palm within a radius of 2m. Thus the root spread coconut plantations all-the uninterrupted growth of other horticultural crops.

The penetration of sunlight in coconut gardens also favours multi-storey cropping system. The venati structure of the coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. The leaves in a coconut palm crown are not randomly distributed but clumped around growing point. This non-random distribution will greatly influence photo synthetically active radiation (PAR). Based on the growth habit of palm and amount of light transmitted through its canopy, the life span of coconut palm can be divided into three distinct phases viz. planting till full development of canopy (about 8 years), young palms (8-25 years) and later stage palms (more than 25 years) The plantations which are in the age group below 8 years have good light transmission and is recommended for cultivating mainly annuals and biennials. The light transmission reduces as the palms grow and this period is ideal for growing shade loving crops. Once the plantation crosses the age of 25 years; maximum light penetration happens and is ideal for taking up perennial crops in this period. (CPCR1,2005)

In Indian conditions the most recommended multi-storey cropping system is a combination of coconut with black pepper, cocoa and pineapple. In other coconut growing countries like Philippines, Sri Lanka etc crops like betel, pepper, cinnamon, papaya, taro, coffee are also recommended.



Principles of multi-cropping system

Commonly cropping system refers to temporal and spatial arrangement of crops and management of soil, water and vegetation in order to optimize the biomass production per unit area, per unit time and per unit input. Key of successful of multistoried cropping system is the crop with diverse feature (growth habit, root depth and crop duration) such as coriander, radish, beetroot, cluster bean, cowpea etc. are useful in making multi-tier cropping system. Growing more than one crop at a time in the same field, farmers minimize soil erosion, which are the

serious drawback of monoculture cropping system. The practice of multi storey cropping system is highly successful in plantation crops such as coconut, arecanut, cashew and coffee for enhancing sustainable productivity and realizing higher income per unit area. The basic principles of multi storied cropping system are (i) opportunities for crop diversification on scientific, ecological and economic principles. (ii) Maximize system productivity. (iii) Utilization of resources with higher efficiency. (iv) Intensive input use and (v) Sustainability of farm resources & environment on long term perspective.

Scope of multi-storey cropping system

Coconut based multi-storey cropping system is gaining popularity among farming community mainly attributed from the benefits like increase in income from unit holdings, assured markets for one crop or another at a time, maximum and efficient utilization of resources, crop diversification etc. In Indian

a) Increase in nut and copra production

The coconut production and copra yields improve especially in the initial years of multi-storey cropping. Margate and Magate (1983) reported that planting of black pepper, pineapple, papaya/cocoa together under coconut increased yield and total profitability of all the crops planted on the same area. Coconuts have a synergistic effect, resulting in higher coconut yield in multiple cropping systems (Nampoothiri et.al, 2018). The impact of intercropping on coconut yields has been studied as companion crops grow vigorously and deplete nutrients and soil moisture. Experiments revealed that the yields are not decreasing over time when management practices were appropriate for each crop (Gunasekaran et.al,2017). Increased nut yields are achieved under the introduction of companion crops over five years (Maheswarappa et.al,2005). The coconuts benefitted very likely from the additional fertilizers applied on the intercrops, in addition to spinoffs from weed management and cultivation, thereby increasing yield.

b) Improving the income

Multi-storey cropping system offers great potential for increasing the income of small and marginal farmers. Coconut when cultivated as monocrop offers the income only from coconut and its bye-products. The multi-storey cropping system help farmer to double the income from plantations. The additional income realized from the intercrops protects the farmers from price fluctuations of coconut and coconut products in the market.

c) Sustainable and circular agriculture

The move to multi-storey cropping is a move towards sustainable agriculture through recycling and reuse of plant wastes. The crop residues from different intercrops can be incorporated to improve the soil organic matter content. Multi-storey cropping system promote reuse and recycling of waste water among all crops, reduce dependence on external inputs, circulate the nutrients among the companion crops, regenerate the soil and minimize impact on the microenvironment.

d) Improving the micro environment

Coconut plantations with multi-storey cropping system tends to have improved soil organic matter.

Priorities and emerging trends

The emerging trends in coconut cultivation specifically in the field of multi-storey cropping are the following

New and exotic crops

Coconut based multi-storey cropping systems with crop combinations are being experimented. High value agricultural crops, cut flowers, exotic fruit crops are few crop combinations that are suited as companion crops in coconut based multi-storey cropping system.

Agri-based business

The integration of coconut based multi-cropping paves the way for starting of different Agri-start ups Coconut plantations integrated with multiple farming systems including dairy, pisci-culture, bee keeping etc earn additional income to the farmers.

Carbon sequestration

Coconut based multi-storey cropping system is also useful in carbon sequestration. Global warming attributed from the increasing levels of green house gases is causing adverse impact on agriculture Sequestration of atmospheric carbon in the plant biomass and soil is one of the vital strategies to alleviate the climate change impact. Coconut plantations with prolonged lifespan offer substantial carbon sequestration potential. The high standing bio mass storage capacity of coconut plantations also add to the carbon sequestration potential. The coconut plantations with multi cropping systems have higher biomass storage capacity than the monocropped ones. The circular nuclear loops in coconut multi cropping systems also the biomass by way of recycling organic matter.

Conclusion

Coconut based multi-storey cropping has been practiced in small holdings, but the same need to popularized in large scale plantations with a perspective of food security, land productivity, crop diversification, resource utilization, economic viability etc. The conversion from monocropping to heterogenous multi cropping is advantageous as it avoids the environmental and social issues associated with monocropping. Multi-storey cropping systems based on coconut can cater to the sustainable goals. Research and development programmes orienting towards development of more cropping models including exotic and high value horticultural crops are the need of the hour. Coconut plantations with multi-storey cropping having immense potential in offsetting the carbon emissions are the future strategies for research programmes.

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CARBON FARMING AND ITS SCOPE UNDER CLIMATE-SMART AGRICULTURE

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Abstract

As the world grapples with climate change, agriculture is under pressure to reduce its environmental footprint while ensuring food security. Carbon farming emerges as a vital practice in this scenario, leveraging natural processes to sequester atmospheric carbon into soil and biomass. This article explores the fundamental concepts, mechanisms, and practices of carbon farming and aligns them with the broader goals of Climate-Smart Agriculture (CSA). Through a combination of biological carbon sequestration, improved land use, and policy support, carbon farming offers a path toward climate mitigation, adaptation, and increased agricultural productivity. Drawing examples from India and global contexts, the article emphasizes the transformative potential of carbon farming and the urgent need to scale its adoption through incentives, capacity-building, and robust verification systems.

Keywords - Carbon sequestration, sustainable agriculture, climate-smart practices, soil health, carbon credits

Introduction

The agriculture sector faces a dual challenge feeding a growing population and combating climate change. Traditional farming practices contribute significantly to greenhouse gas (GHG) emissions, particularly through deforestation, soil degradation, livestock emissions,

and synthetic fertilizers. However, agriculture also holds the unique potential to act as a carbon sink through sustainable practices collectively known as carbon farming.

Carbon farming refers to a set of land management strategies aimed at **capturing atmospheric carbon dioxide (CO₂)** and storing it in **soil organic matter and vegetation**. This not only mitigates climate change but also improves **soil fertility, biodiversity, and water retention**.

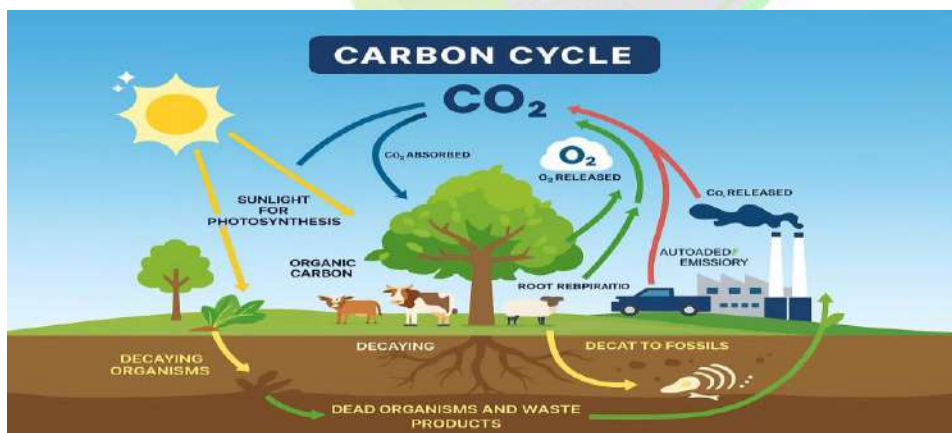
In the context of **Climate-Smart Agriculture (CSA)** an approach defined by the FAO to increase productivity, enhance resilience, and reduce emissions carbon farming plays a central role. It addresses the triad of sustainability goals by improving yields, building climate resilience, and contributing to carbon neutrality.

Understanding Carbon Farming

Carbon farming operates on ecological principles that enhance the natural ability of plants and soil microbes to absorb and retain carbon. The **carbon cycle** in agriculture involves carbon inputs through plant residues, compost, and root biomass and carbon losses through tillage, erosion, and respiration.

Practices under carbon farming focus on:

- **Minimizing carbon loss** (e.g., through reduced tillage),
- **Increasing carbon input** (e.g., through cover crops, agroforestry),
- **Stabilizing carbon in soils** (e.g., through biochar and mulching).



Key Practices in Carbon Farming

1. Agroforestry

Agroforestry involves integrating trees with crops and/or livestock. Trees act as long-term carbon sinks and offer co-benefits such as shade, windbreaks, and habitat for biodiversity.

Benefits:

- Sequesters carbon in biomass and soil
- Enhances farm microclimate and reduces erosion
- Provides timber, fodder, and fruit for income diversification

2. Conservation Tillage

Conservation tillage minimizes soil disturbance, preserving soil aggregates and carbon stored within them. No-till and strip-till methods are popular forms.

Advantages:

- Reduces CO₂ release from the soil
- Improves water retention
- Minimizes soil erosion

3. Cover Cropping

Cover crops such as legumes or grasses are grown between planting seasons to protect the soil and enhance organic matter.

Functions:

- Adds biomass to soil
- Enhances nitrogen fixation (in legumes)
- Suppresses weeds and prevents erosion

4. Organic Amendments

The application of organic inputs like **compost**, **farmyard manure**, and **green manure** increases microbial activity and soil carbon levels.

5. Biochar Application

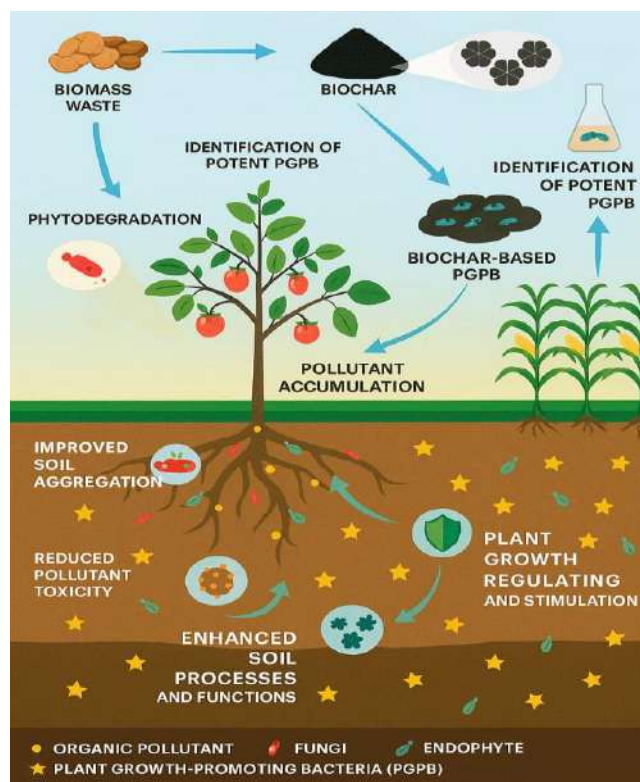
Biochar is a stable form of carbon produced by pyrolyzing organic matter. When added to soil, it remains stable for centuries.

Benefits:

- Long-term carbon storage
- Enhances soil structure
- Reduces nutrient leaching

6. Improved Livestock Management

Rotational grazing and forage optimization increase vegetative cover and reduce methane emissions from poorly managed livestock systems.



Soil layers showing biochar and root biomass accumulation.

Carbon Farming and CSA: A Strategic Alignment

The goals of **Climate-Smart Agriculture** productivity, adaptation, and mitigation align closely with carbon farming:

CSA Goal	Carbon Farming Role
Increased Productivity	Enhances soil fertility, nutrient cycling, and water use efficiency
Adaptation	Builds resilience to droughts, floods, and extreme climate events
Mitigation	Sequesters atmospheric carbon and reduces GHG emissions

Global and Indian Perspectives

Global Initiatives

- **4 per 1000 Initiative (France):** Aims to increase soil carbon stocks by 0.4% per year to combat climate change.
- **FAO Soil Partnership:** Promotes sustainable soil management for carbon storage.
- **IPCC Support:** Endorses land-based solutions like carbon farming for climate mitigation.

Indian Programs and Pilots

India, with over 160 million hectares of cultivated land, has initiated several policy and research programs:

- **National Mission for Sustainable Agriculture (NMSA)**
- **Soil Health Card Scheme**
- **Paramparagat Krishi Vikas Yojana (PKVY)** promoting organic farming
- **Agroforestry Mission** under the National Agroforestry Policy (2014)

Carbon Credits and Market Linkages

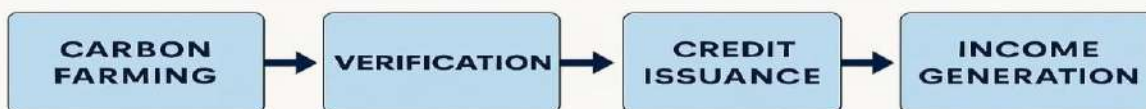
A key incentive for carbon farming lies in **carbon credit trading**. By measuring the amount of carbon sequestered, farmers can sell credits to buyers (corporates, governments) seeking to offset emissions.

Process Overview:

1. Farmer adopts a carbon farming practice.
2. Sequestration is measured by a third-party verifier.
3. Credits are issued and sold on voluntary markets.

Examples:

- Smallholder coffee growers in Karnataka earned revenue through carbon credits using shade trees and residue retention.
- NGOs like WRI India and FairClimate Network help aggregate and verify credits from smallholders.



Measurement, Verification, and Certification

Carbon sequestration must be **measurable, reportable, and verifiable (MRV)** to generate tradeable credits.

Technologies Used:

- Soil carbon testing kits

- Remote sensing and satellite imagery
- AI-based predictive models

Certification Bodies:

- Verra (VCS)
- Gold Standard
- Plan Vivo

Challenges to Scaling Carbon Farming

Challenge	Explanation
Lack of Awareness	Many farmers are unaware of carbon benefits and credit systems
Verification Complexity	MRV procedures are expensive and technically demanding
Land Fragmentation	Small farm sizes make certification less viable unless aggregated
High Initial Costs	Transitioning from conventional to sustainable systems can involve expenses
Market Uncertainty	Carbon credit prices vary and policy frameworks are still evolving

Solutions:

- Incentivized support through CSR and government schemes
- Capacity-building for FPOs and rural youth
- Simplified, mobile-based carbon calculators for field use

Case Studies from India

Andhra Pradesh Agroecology Project

Adopted natural farming techniques across 6 lakh hectares. Soil carbon levels rose by 15% over four years, reducing fertilizer dependency.

Punjab Conservation Agriculture Network

Adoption of no-till wheat on over 1 million hectares. Significant carbon savings from reduced diesel use and improved soil organic matter.

Bundelkhand Agroforestry Cluster

Community-level agroforestry increased carbon sequestration by 3 tonnes/ha/year. Generated additional fodder and fuelwood for rural households.



Conclusion

Carbon farming stands at the confluence of climate action, sustainable development, and rural livelihood enhancement. When implemented effectively, it transforms agriculture into a regenerative enterprise capable of healing the environment while feeding the population. With India's growing commitment to climate goals under the Paris Agreement and its increasing agricultural vulnerability, integrating carbon farming into mainstream policy is a strategic necessity. Bridging knowledge gaps, creating enabling markets, and adopting digital MRV tools will be crucial to unlocking its full potential. As global interest in nature-based solutions surges, carbon farming offers an inclusive and resilient pathway toward climate-smart agriculture and ecological balance.

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HYDROPONIC FODDER FOR LIVESTOCK NUTRITION: MODERN APPROACHES

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Introduction

Using water, nutrients, and a growing substrate, hydroponics is a contemporary method of producing cattle feed. Hydroponic fodder is grown under controlled settings with water and nutrients, as opposed to traditional forages methods that depend on soil and weather. It could develop into a reliable supply of superior livestock feed. The idea of hydroponic fodder has become incredibly popular in modern animal production. Using nutrient-rich water solutions, fodder is grown in a regulated, soilless environment as part of a novel approach to animal nutrition. In contrast to conventional techniques that rely on weather and soil quality, hydroponic fodder systems offer a steady and dependable supply of high-quality animal feed. Because of its effectiveness, sustainability, and capacity to generate fodder of better quality independent of environmental conditions, this technique has seen a sharp increase in popularity. For animals to be healthy and productive, feed must be nutrient-rich and efficient. In this sense, hydroponic feed is unique since it provides a greater concentration of vital nutrients that are important for the health of the animals. The ideal absorption of these nutrients by plant roots is made possible by the regulated hydroponic environment, which makes the feed for cattle more nutrient-dense and easily digested. Higher-quality items like meat and milk, better health, and increased reproductive efficiency are all directly correlated with this increased nutritional content.



Understanding Hydroponic Fodder

Hydroponic fodder is a revolutionary method that redefines the way we cultivate feed for livestock by eliminating the need for soil. In traditional farming, soil serves as the medium for plant growth, providing nutrients to the roots. However, hydroponic fodder systems bypass this conventional approach. In this method, plants are grown on specialized racks or beds, using an inert substrate instead of soil. The absence of soil allows for precise control over the nutrient composition delivered to the plants. Nutrients are dissolved in a water solution, and plant roots directly access these, resulting in rapid, robust growth.

One of the key advantages of hydroponic fodder lies in the controlled environment in which it is cultivated. Unlike traditional farming methods vulnerable to the unpredictability of weather and soil conditions, hydroponic systems provide a meticulously managed setting. This control over factors such as temperature, humidity, and nutrient levels ensures a consistent and optimal growing environment. The impact is profound—farmers can guarantee a year-round supply of fresh, high-quality forage for their livestock. This predictability is a game-changer, offering stability in the nutritional provision for animals, which, in turn, significantly influences their health, growth rates, and overall productivity. The controlled environment of hydroponic fodder systems emerges as a cornerstone in the pursuit of sustainable and superior-quality livestock nutrition.

Advantages of Hydroponic Fodder for Livestock:

By removing the requirement for soil, hydroponic fodder is a ground-breaking technique that completely changes how we grow feed for animals. In conventional farming, soil acts as a growing substrate for plants, giving their roots nutrition. Hydroponic fodder systems, on the other hand, avoid this traditional method. This technique uses an inert substrate in place of soil to grow plants on specific racks or beds. Because there is no soil present, the nutrients that are supplied to the plants may be precisely controlled. Plant roots directly access dissolved nutrients in a water solution, which promotes strong, quick growth. Compared to conventional pasture, hydroponic fodder has higher concentrations of vital proteins and vitamins, making it a nutritional powerhouse for animals. The precise nutrient management made possible by the controlled environment produces feed that is both rich and suited to the individual requirements of the animals. This higher nutritional value is essential for improving the animals' general health and vitality. Increased concentrations of vital nutrients make hydroponic fodder a powerful super

food for animals, promoting better muscle growth, immune system performance, and reproductive health.

Hydroponic Fodder System: Following steps



Selecting the Right Space

It is impossible to overestimate the significance of a regulated environment in the field of hydroponic fodder production. Consideration of controlled habitats, such as greenhouses or indoor setups, is essential to maximize growing conditions and provide constant, high-quality feed. Farmers can control variables like temperature, humidity, and light intensity thanks to these settings, which operate as a buffer against the unpredictable effects of the outside world. In example, greenhouses provide a balance between the advantages of indoor and outdoor growing by utilizing natural sunlight and preserving a regulated environment. The key to a successful hydroponic fodder system is investing in a controlled environment, which ensures year-round production and a steady supply of nutrient-rich feed for animals.

Choosing Suitable Crops

Choosing the correct crops is essential in the field of hydroponic fodder to guarantee that cattle are fed a diet high in nutrients. Some crops are particularly noteworthy for their remarkable nutritional value, which makes them perfect for hydroponic growing. Among the best hydroponic fodder crops are alfalfa, barley, and oats since they are strong in protein and include a variety of vital vitamins. These crops support cattle production and general health, which is consistent with hydroponic systems' goal of producing high-quality feed. Furthermore, the versatility of hydroponic systems to local climate conditions is what makes them so beautiful. In contrast to conventional farming, hydroponic systems enable farmers to grow particular crops that are climate-appropriate for their area.

Setting Up Growing Trays or Shelves

Two crucial components require careful consideration for a hydroponic fodder system to thrive: adequate drainage and thoughtful space use. In order to avoid water logging and maintain a healthy and productive hydroponic environment for fodder growth, effective drainage is essential. Root rot, nutrient imbalances, and other problems that could jeopardize the hydroponic system's overall success are avoided by putting in place carefully thought-out drainage systems. The strategic utilization of space is equally important. Hydroponic systems, which are frequently installed indoors or in cramped spaces like greenhouses, greatly benefit from careful spatial planning. This entails using shelves and stacked trays to maximize the vertical space.

Installing an Irrigation System

Any good hydroponic feeding system depends on a steady and dependable supply of water. Since water quality directly affects the delivery of nutrients to the growing fodder, its importance cannot be understated. Thus, a fundamental component of system planning is guaranteeing a steady, contaminant-free water supply that can satisfy the demands of the hydroponic system. Effectiveness is crucial when it comes to irrigation. The drip irrigation system is one of the most effective and economical options among the different types of irrigation systems that are available. By supplying water and nutrients straight to each plant's base, this technique reduces water waste and guarantees exact control over the dosages.

Ensuring Adequate Lighting:

It is impossible to overestimate the significance of proper illumination in the field of hydroponic fodder production, particularly when growing indoors. Artificial lighting can fill the void left by natural sunlight, which isn't always enough. Stressing the importance of proper illumination is essential to preserving steady and ideal development conditions for the feed grown hydroponically.

LED lights stand out as a top choice for people who choose indoor hydroponic systems.

Monitoring and Adjusting Nutrient Levels

Keeping the right balance of nutrients is essential to a successful hydroponic fodder system. The quality and nutritional value of the meal are directly impacted by this delicate balance. It is important to emphasize the importance of this balance for farmers who want to get the most out of their hydroponic systems.



Nutrient solutions are crucial in the hydroponics industry. To help farmers navigate the complexities of hydroponic nutrition, it becomes crucial to talk about typical nutrient solutions and how to apply them. In addition to ensuring healthy plant growth, this concentration on nutrient balance results in feed of the highest caliber, improving the productivity and health of animals.

Managing Temperature and Humidity

A successful harvest for those experimenting with hydroponic fodder systems depends on maintaining ideal conditions. A crucial first step in achieving effective hydroponic farming is offering thorough instructions for preserving these conditions.

Important factors including temperature, humidity, and airflow should all be covered in the guidelines. These elements are essential to the growth and well-being of fodder grown hydroponically. Giving farmers the information they need for a successful harvest will include describing the optimal ranges for each and offering helpful advice on reaching and sustaining them.

Starting a hydroponic fodder production business guarantees a sustainable and high-quality supply of nourishment for cattle while also streamlining the cultivation process. The benefits, which include year-round availability and nutrient density, make hydroponic fodder a game-changing option for contemporary animal husbandry.

INNOVATIVE NUTRITIONAL STRATEGIES TO COMBAT HEAT STRESS AND IMPROVE HEALTH, PRODUCTION AND WELFARE IN POULTRY

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Introduction

Poultry are highly susceptible to heat stress, a condition that significantly impairs health, productivity, reproductive performance and welfare. The global rise in ambient temperatures, exacerbated by climate change, has necessitated the development of novel strategies to alleviate thermal stress in poultry flocks. Heat stress is a critical concern in modern poultry production, especially in tropical and subtropical climates. With global warming exacerbating temperature extremes, the poultry industry faces significant challenges in maintaining productivity, health and animal welfare. Poultry are homeothermic animals with a narrow thermoneutral zone (18–24°C). When ambient temperatures exceed this range, especially beyond 30°C, poultry experience heat stress that adversely affects physiological and metabolic processes.

Heat stress disrupts thermoregulation and induces a cascade of physiological changes. To dissipate excess heat, birds increase respiration, leading to excessive CO₂ loss and alkalosis, which impairs calcium metabolism and egg shell quality. A major consequence of heat stress is anorexia, with feed intake decreasing by up to 5% for each degree above 25°C. Elevated temperatures increase reactive oxygen species (ROS), leading to lipid peroxidation and cellular damage.

Heat stress impairs all production indices such as reduced body weight gain and FCR in broilers, decline in egg production, egg weight and shell quality in layers as well as increased mortality and immune-suppression, making birds more susceptible to infections. Welfare

indicators such as panting, prostration and reduced activity further reflect poor thermoregulation and stress. Therefore, for combating the heat stress in poultry, the some of the most promising intervention strategies are applied. Among these strategies, nutritional interventions offer promising and cost-effective solutions. This article highlights recent advancements and practical innovations in poultry nutrition designed to enhance thermo-tolerance, maintain performance and support animal welfare under heat stress.

Key strategies discussed include dietary electrolyte balance, phytogenic additives, functional amino acids, vitamins and minerals, probiotics, prebiotics and precision feeding technologies. Emphasis is placed on the mechanisms by which these interventions mitigate physiological stress, maintain feed intake and improve immune response. Furthermore, this paper explores the synergistic role of nutritional management and environmental controls, providing integrative insights into sustainable poultry production systems under challenging climatic conditions. Therefore, proper innovative nutritional strategies and intervention can minimize the adverse effects of heat stress different classes of poultry.

Challenge of heat stress in poultry

Heat stress occurs when poultry are unable to maintain thermal balance due to high ambient temperatures, often above 28–30°C, combined with high humidity. Birds lack sweat glands and rely on panting to dissipate heat, which leads to respiratory alkalosis, oxidative stress, and reduced feed intake.

Economic and welfare implications

Heat stress results in:

Decreased feed conversion efficiency, reduced egg production and quality, lower growth rates and meat yield, increased mortality and susceptibility to disease and compromised welfare indicators (panting, reduced activity, aggression). With climate change accelerating, the need for sustainable and innovative nutritional strategies is more urgent than ever.

Physiological impacts of heat stress on poultry

Metabolic and hormonal disruptions

Heat stress affects the hypothalamic–pituitary–adrenal (HPA) axis, increasing corticosteroid levels, which suppress immunity and growth. Metabolic changes include reduced thyroid hormone activity (T_3 and T_4), increased reactive oxygen species (ROS) and dehydration and electrolyte imbalance

Gastrointestinal health

High temperatures impair gut integrity and microbial balance, leading to:

Increased gut permeability (leaky gut), dysbiosis and impaired nutrient absorption

Innovative nutritional strategies**Electrolyte supplementation and acid-base balance****Sodium, potassium and chloride**

The dietary electrolyte balance ($DEB = Na^+ + K^+ - Cl^-$) is critical in maintaining acid-base homeostasis. Optimal DEB during heat stress ranges from 250–300 mEq/kg diet. It is optimal during heat stress.

Sources: Sodium bicarbonate @ 0.3–0.5% in feed, Potassium chloride @ 0.2–0.4% in feed and Ammonium chloride (acidifier) @ 0.25 to 0.5% in feed i.e. 2.5 to 5 kg/metric ton of feed

Benefits

Improved water retention, reduced panting and alkalosis, enhanced feed intake, restores acid-base balance and reduces mortality

Phytogenic feed additives (PFAs)

These include essential oils, herbs, and plant extracts such as: Oregano, thyme, cinnamon, turmeric and ginger.

Bioactive compounds: flavonoids, tannins, saponins

Herbal extracts and essential oils have antioxidant, antimicrobial and appetite-stimulating effects. Turmeric (*Curcuma longa*): @ 0.5–1% of diet, oregano oil: @ 150–300 mg/kg feed, thyme or cinnamon: @ 0.5–1% of diet.

Mechanisms of action

Antioxidant, anti-inflammatory, antimicrobial (supports gut health) and appetite stimulation

Example: Oregano oil improves FCR, enhances gut health and reduces rectal temperature in heat-stressed broilers.

Functional amino acids

Certain amino acids have thermoregulatory and immunomodulatory effects in the poultry. Such as:

Methionine and cysteine

Sulfur-containing amino acids with strong antioxidant potential, support glutathione

synthesis. Supplemented @ Up to 10–20% above recommendations during stress

Benefit: Enhance antioxidant capacity via glutathione synthesis

Arginine

Enhances nitric oxide (NO) synthesis → vasodilation and boosts immune function

Supplemented @ 1.2–1.5% of diet in broilers

Betaine

Osmolyte that stabilizes cell hydration improves energy efficiency by reducing heat increment of feeding. Betaine supplemented @ 0.1–0.2% in diet, acts as an osmoprotectant and methyl donor, improved FCR and resilience during heat stress.

Vitamins and antioxidants

Heat stress increases oxidative stress; **vitamins** help combat ROS.

Vitamin C

Non-essential in poultry, but beneficial during stress, improves feed intake, growth and immunity. Reduces corticosteroid levels, improves feed intake and supports immune function.

Dose: 200–300 mg/kg of feed or 250 mg/L of drinking water.

Vitamin E and selenium

Synergistically enhance antioxidant defence, reduce lipid per-oxidation. Scavenges free radicals, improves fertility and egg production in layers. Vitamin E supplemented @ 250–500 mg/kg feed. Selenium (organic or inorganic) works synergistically with vitamin E to combat oxidative damage. Selenium supplemented @ 0.3–0.5 mg/kg feed.

B-complex vitamins

Supplementing poultry diets with B-complex vitamins is important for supporting metabolic functions, energy production, nervous system health, immune function and resilience to stress. Below is recommended doses of B-complex vitamins for poultry (especially broilers and layers), with notes on stress conditions and metabolic support.

Typical doses of B-complex vitamins in poultry feed (per kg of feed)

Vitamin	Normal dose	High-stress dose	Functions
Thiamine (B ₁)	1–2 mg	3–5 mg	Carbohydrate metabolism, nerve function
Riboflavin (B ₂)	3–6 mg	8–10 mg	Energy metabolism, skin and eye health

Niacin (B ₃)	15–60 mg	80–120 mg	Energy metabolism, anti-dermatitis, heat stress support
Pantothenic Acid (B ₅)	8–12 mg	15–20 mg	Fatty acid metabolism, adrenal function
Pyridoxine (B ₆)	2–4 mg	5–6 mg	Amino acid metabolism, nervous system
Biotin (B ₇)	0.15–0.30 mg	0.3–0.5 mg	Skin, feather health, enzyme cofactor
Folic Acid (B ₉)	0.5–1 mg	2–4 mg	DNA synthesis, red blood cell production
Cobalamin (B ₁₂)	10–20 µg	30–50 µg	Red blood cell formation, nervous system, growth

Key considerations

Stress factors: Heat stress, disease, vaccination, transport or nutritional stress increases B-vitamin requirements.

Formulation: Often provided in a vitamin premix, balanced for breed, age and production goal.

Water-soluble doses: In acute stress, B-complex vitamins can be administered via drinking water for 3–5 days (e.g., B-complex at 2–5 mL/L depending on the formulation).

Toxicity: B vitamins are generally safe with wide margins; excesses are typically excreted due to water solubility, though cost and feed balance should be considered.

Benefits of optimized B-complex supplementation

Improved feed conversion ratio (FCR), better weight gain and growth rate, enhanced immune response and vaccine efficacy, reduced oxidative stress and mortality under heat or transport stress, improved egg production and shell quality in layers.

Probiotics, prebiotics and synbiotics

Gut health is central to immune and productive performance under heat stress.

Probiotics

Live beneficial bacteria (e.g., *Lactobacillus* spp., *Bacillus subtilis*), modulate immune response and prevent pathogens.

Dose: 1×10^8 CFU/kg feed

Benefit: Enhance gut integrity, modulate immunity, reduce pathogen load, promote growth of beneficial bacteria and reduce intestinal inflammation

Prebiotics: Non-digestible fibres (MOS, FOS), feed the beneficial microbes @ 0.5–1% of diet

Synbiotics: Combined action enhances gut integrity and absorption efficiency

Use of organic acids

Organic acids (citric, formic, butyric acid) maintain gut pH and control pathogens.

Citric acid: 0.5–1% of feed and butyric acid: 0.1–0.2% of feed.

Mode: Stabilizes gut pH, improves nutrient absorption and reduces gut pathogens

Benefits:

Improved nutrient digestibility, enhanced villi height and gut morphology, reduced enteric pathogens

Energy density and fat supplementation

Fat vs. carbohydrates

Fats generate less metabolic heat than carbohydrates. Fat provides high energy with low heat increment (Fat; 9 Kcal vs. Carbohydrate; 4 Kcal).

Recommended fats: Vegetable oils (soybean, palm and Sun flower): 3–5% of the diet

Medium-chain triglycerides (MCTs): Up to 2%

Effect: Improves growth rate, lowers respiratory rate, enhances energy utilization

Results: Better energy utilization, lower respiratory rate and heat production

Hydration and nutrient density

Water management

Electrolyte-fortified water (e.g., 1g NaHCO₃ + 1g KCl per litre)

Cooling or misting systems integrated with water delivery

Concentrated diets

High-nutrient, low-volume diets support intake when appetite drops

Use pelleted or crumbled diets to reduce energy expenditure on digestion

Precision nutrition and smart feeding

Phase feeding

Adjusting feed formulation to age and temperature stress levels.

Feed timing

Feeding during cooler hours (early morning/evening) improves intake.

Precision technologies

Sensors to monitor bird behaviour and environmental conditions, AI-based diet formulation

Integration with management and environmental controls

Nutrition alone is not sufficient success comes from integrated strategies.

Housing design

Adequate ventilation, insulation, and shading, evaporative cooling systems

Stocking density

Lower densities reduce heat load and competition.

Lighting programs

Dimming lights or intermittent lighting reduces metabolic heat production.

Case studies and research evidence

University trials

Studies have shown:

Vitamin C and E supplementation increased growth by 10–15%

Betaine improved FCR under 35°C by 0.1–0.2 points

Electrolyte balance improved survivability by 12% in layers during heat waves

Field applications

Integrated farms in tropical zones successfully applied:

Feed additive blends (phytogenics + probiotics), smart climate-responsive feeders, water cooling systems with electrolytes

Future directions

Genotype–nutrition interactions

Heat-tolerant breeds combined with targeted nutrition offer resilient production.

Nutri-genomics

Exploring gene expression changes due to dietary interventions during heat stress.

Sustainable feed sources

Insects and algae as novel ingredients and fermented feeds for improved digestibility

Conclusion

Heat stress continues to pose a significant challenge in poultry production by impairing performance, immunity, and welfare. Innovative nutritional strategies, particularly those targeting antioxidant defences, electrolyte balance, gut health, and energy efficiency, offer



practical and effective tools to mitigate these impacts. Supplementation with specific doses of vitamins (e.g., C, E), amino acids (arginine, betaine), and feed additives (electrolytes, phytogenics, probiotics) has been scientifically validated to improve thermo-tolerance and maintain productivity. Integrating these approaches with smart management practices will ensure sustainable poultry production in heat-prone environments.



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VIKSIT KRISHI SANKALP ABHIYAN – PRE KHARIF CAMPAIGN FOR ENLIGHTENING FARMERS at KRISHI VIGYAN KENDRA, GHANTASALA

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Introduction

The Viksit Krishi Sankalp Abhiyan campaign aligned with the vision of Prime Minister Shri Narendra Modi ji for a *self-reliant and sustainable India*, and seeks to promote the widespread adoption of advanced agricultural and other allied technologies across the nation. Under the guidance of the Honourable Agriculture Minister Shri. Shivraj Singh Chouhan ji, ICAR – ATARI Zone – X had organized Viksit Krishi Sankalp Abhiyan- 2025 through Krishi Vigyan Kendras (KVKs).



Krishi Vigyan Kendra, Ghantasala, Krishna district, Andhra Pradesh conducted Viksit Krishi Sankalp Abhiyan (VKSA) from 29th May to 12th June, 2025. Dr. D. Sudha Rani, programme Coordinator, KVK, Ghantasala was nominated as nodal officer by ICAR – ATARI

Zone – X, Hyderabad. During this campaign, six (6 No) teams were formed with the scientists of KVK who acted as team leaders i.e., Team 1: Dr. V. Manju Vani, SMS (Horticulture); Team 2: Dr. B. Naveen, SMS (Agril. Extension); Team 3: Smt. G. Krishnaveni, SMS (Home Science); Team 4: Dr.

M. Venkata Lakshmi, SMS (Crop Production); Team 5: Dr. K. Revathi, SMS (Plant Protection) and Team 6: Sri. J. Yaswanth Kumar, SMS (Fisheries) and ICAR scientists from Indian Institute of Oil palm Research (IOPR), Pedavegi; State Agricultural university (ANGRAU) – Scientists from ARS, Ghantasala, ARS, Machilipatnam and SRS, Vuyyuru. In total, 6 teams have so far conducted 45 team visits covering 155 villages and connecting 15057 farmers to the campaign.

Campaign

The main objective of this campaign was to interact and discuss with the farmers to increase the productivity and income of farmers. Through this campaign farmers were enlightened on various key topics such as sub division wise suitable varieties of paddy for ensuing kharif season and crop management practices; Soil fertility management - Use of liquid biofertilizers and organic manures in fertility management; Importance of soil sampling and soil test-based fertilizer management; Demonstration of drone technology; Integrated pest and disease management in major crops; Role of bioagents in insect pest and disease management; Effects of excessive use of pesticides and crop residues; ICM practices in oil palm and other Horticulture crops; Importance of backyard poultry farming, maintenance and vaccination schedules; Care & maintenance of cattle and Importance of balanced diet in adolescent girls and rural women.

For this awareness programmes, public representatives like Sri Mandali Buddha Prasad garu, hon'ble MLA, Avanigadda constituency and Sri Varla Kumar Raja garu, Hon'ble MLA, Pamarru constituency attended as Chief guests and had given their valuable suggestions to the farming community. Dr. G. Sivanarayana, Director of Extension, ANGRAU attended as special guest and addressed the farmers on latest technologies.

Conclusion

Farmers expressed their gratification towards conduct of timely awareness programmes wherein the key aspects covered during the campaign like selection of suitable varieties, demonstration of drone technology etc., were found beneficial.

LESSER –KNOWN LEAFY VEGETABLES FOR FOOD AND NUTRITIONAL SECURITY

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Abstract

Plants are gifts of God for mankind. In India most rural inhabitants depend on wild edible plants to meet their additional food requirements and to attain household food security. India, being blessed with diverse climatic conditions, has a wide array of edible green leafy vegetables (GLV) some of which are locally grown and utilized from ancient periods as source of food as they contain many nutrients and minerals which can nourish the ever growing human population and helps to attain nutrient security. Many of these greens are growing as weeds in the crop fields which are resilient, adaptive and tolerant to adverse climatic conditions and need less investment and don't require much investment, hence it is described as 'poor man's vegetables'. Although, they can be raised at lower management costs even on poor marginal lands, they have remained underutilized due to lack of awareness and popularization of technologies for utilization. It is essential that the locally available GLV, which are inexpensive and easy to cook, be used in the diets to eradicate micronutrient malnutrition and also to prevent the degenerative diseases.

Keywords: Underutilized; Leafy vegetable; Nutrition security

Introduction

Vegetables are crucial for a balanced human diet and global nutritional security as they provide essential nutrients, vitamins, and minerals. In spite, varieties, hybrids, and production technologies are good; many underutilized vegetable crops are needed to be considered. These underutilized crops, which are not grown commercially or traded widely, suffer from limited availability of planting material, lack of awareness regarding their nutritional and medicinal

importance. India's climate and soil are favorable for producing various underutilized vegetables. The government has taken steps to promote their importance. Hence, increasing production of underutilized vegetables can alleviate nutritional problems, create employment, boost rural incomes, and contribute to the national economy as well if considered scientifically and propolicy manners.

Importance of fruits and vegetables in the daily human diet promotes and recommends the consumption of 400 g of fruits and vegetables per day to provide necessary nutrient lacking in other food groups (WHO 2003). With the increasing epidemiological support on benefit of vegetable consumption on health, Indian Council of Medical Research (ICMR) recommended 300 g vegetable consumption (125 g leafy vegetable, 100 g root and tuber and 75g fruit vegetable) per capita per day. The diversity and quality of food produced and consumed is a decisive factor when addressing the triple burden of malnutrition, i.e., undernutrition, micronutrient deficiency, and over-nutrition. Although fruit and vegetables are usually mentioned jointly when addressing malnutrition, this article focuses mainly on the compilation and review the role of both global and traditional vegetables in addressing nutritional security and human health.

Biodiversity and traditional Leafy vegetables

There exists a vast resource of undermined plants that can help partly alleviate current problems of malnutrition and under-nutrition, especially in rural areas where malnutrition is increasingly being seen as a consequence of enforced dependence on external food resources mostly obtained from large scale commercial agriculture systems. Green leafy vegetables (GLV) are a part of the larger biodiversity and are an integral part of the diets in eastern India in states like Odisha and West Bengal. They play a significant role in our nutrition and diet and are also used as medicine since ancient times. They are also important sources of protective foods.

Traditional leafy vegetables and food and nutrition security

Several studies have reported that indigenous leafy vegetables address gaps in nutrition by providing wholesome, reasonably priced and nutrient-dense food substitutes. Even though traditional leafy vegetables (TLV) have not been fully exploited in the quest to achieve food safety and alleviate malnutrition, many researchers agree that the vitamins, minerals, and phytochemicals with strong antioxidant properties and nutritional (micronutrient) content in TLVs are their most valuable attributes. The capacity of a food to provide nutrients is of great

importance in food security. Indigenous leafy vegetables are diverse and include many different species. Globally, over 7000 species of leafy vegetables are either cultivated or harvested from the wild for food. Amongst these, ILVs that vary in shape, size, colour, taste and nutritional value are consumed in nearly all countries. Traditional leafy vegetables offer a higher nutritional value and would ensure an appropriate supply of those nutrients identified to be lacking if they are consumed in suitable proportions. Since they contain significant amounts of vitamins, pro-vitamin A in particular, they are highly beneficial since they maintain health and prevent diseases. As an antioxidant, vitamin A plays an important role in preventing free oxygen radicals from causing damage to cells and, by so doing, reduces the incidence of some cancers, heart attacks, brain strokes, and maintains eyesight and the immune, skeletal, respiratory, reproductive, and integumentary (skin) systems. Traditional leafy vegetables are rich sources of polyphenols, flavonoids, amino acids, minerals, vitamins A and C, B-carotene and dietary fibre.

These bioactive components are involved in protection against various conditions including cancer, diabetes mellitus, arthritis and more. These species are also found as rich in phytonutrients. Their leaves contain significant amounts of major and micronutrients. Species like punarnava, carpet weed, small water clover, flame flower, smooth joy weed and watercress have high nitrogen content (>3.00%) while smooth joy weed and Chinese spinach are rich in potassium (>1.50%). Watercress is found to have a high amount of Ca and Mg when compared with the underutilized species. Watercress, dwarf copper leaf, Asiatic pennywort, and carpet weed are rich in Fe and Mn content. Chinese Spinach, Smooth joy weed and flame flower are also found to have high amounts of Manganese. Asiatic Pennywort, buffalo spinach and watercress have high amounts of Zinc in their leaves. Cu is found to be high in buffalo spinach, Chinese fever vine and flame flower leaves on a dry weight basis.

There is a necessity to characterize these important indigenous leafy vegetables for their phytonutrient contents and promote their consumption among rural and tribal communities where malnutrition, hunger and hidden hunger are prevailing problems. They are the cheaper source of nutrients and vitamins. Because of their short-duration nature and low input cultivation, they can easily fit in any cropping or farming system. Some of these vegetables like Amaranthus, Palak and Ipomea species are tolerant to adverse environmental conditions such as soil acidity and salinity. Few of them are aquatic vegetables suitable for waterlogging conditions and flood-prone areas. Therefore, their cultivation in diversified cropping system models not

only enhances income and health but also reduces the risk that arises due to climate change. Few of these indigenous leafy vegetables of Odisha are not being cultivated commercially and a detailed package of practices are not available. Hence, there is a need to develop a package of practices for these crops. Besides, there is also a necessity for promoting these indigenous vegetable cultivation and consumption among the farmers by creating awareness programmes and training.

Table 1: Some of the important traditional and lesser known leafy vegetables with scientific details

Sl. No	Local Name	Scientific Name	Family	Season of Availability
1	Mati Poi	Talinum portulacifolium	Portulacaceae	Mostly rainy season
2	Ghoda Puruni	Boerhavia diffusa	Nyctaginaceae	Rainy season
3	Lata saga	Rivea hypocrateriformis	Convolvulaceae	Throughout the year
4	Sunsunia	Marsilea polycarpa	Marsiliaceae	Rainy
5	Kansiri saga	Commelina benghalensis	Commelinaceae	Rainy, post-rainy
6	Pasaruni	Paederia foetida	Rubiaceae	Summer, rainy
7	Puruni saga	Portulaca oleracea	Portulacaceae	Summer, rainy
8	Madaranga	Alternanthera sessilis	Amaranthaceae	Rainy
9	Gayasa	Leucas aspera	Lamiaceae	Rainy
10	Pita saga	Glinus oppositifolius	Molluginaceae	Summer
11	Kalam saga	Ipomoea aquatica	Convolvulaceae	Rainy
12	Kansiri saga	Commelina benghalensis	Commelinaceae	Rainy
13	Bana dhania	Eryngium foetidum	Apiaceae	Mostly rainy, winter (shade)
14	Pancha patri	Euphorbia spp	Euphorbiaceae	Winter/rainy
15	Kuler	Bahunia spp	Fabaceae	Throughout year

16	Hidmilchi	Enhydra fluctuans	Asteraceae	Summer/rainy
17	Khata saga	Oxalis corniculata	Oxalidaceae	Rainy
18	Kolkata madaranga	Alternanthera spp	Amaranthaceae	Summer
20	Bathua saga	Chenopodium album	Chenopodiaceae	Winter
21	Sunsunia saga	Marsilea polycarpa	Marsiliaceae	Rainy
22	Agasti	Sesbania grandiflora	Fabaceae	Perennial
24	Muthi saga	Polygonum plebeium	Polygonaceae	Rainy/winter

These underutilized leafy vegetables have several medicinal properties. Albeit the medicinal properties associated with these crops are not yet scientifically proven in the majority of these crops, they are being constantly used by the rural/tribal communities based on the traditional knowledge that travelled generation after generation through hearsay. The below table houses the medicinal properties of these species based on indigenous traditional knowledge.

Table-2: Medicinal properties of the underutilized species based on Indigenous Traditional Knowledge

S. No.	Content	Indigenous Traditional Knowledge
1	Flame Flower	The leaves are used by the local inhabitants against constipation
2	Asiatic Pennywort	The leaves are used as tonic for improvement of brain power. It is also used against many skin conditions and healing of wounds
3	Small Water Clover	The leaves are used for improving the digestion. It is also used as aphrodisiac. Leaves are also used for increasing eye-sight for greater visibility
4	Chinese Spinach	The plant juice is used as an emetic
5	Dwarf Copperleaf	The stems and leaves are used against eye related ailments. People use it as a cooling agent to decrease the high fever and as an ingredient for hair oil. Decoction with little salt is drunk to check blood vomiting.
6	Midnapore Creeper	The tribal people use the plant for its ethno-medicinal uses in

		treating cough, headache, and skin disease.
7	Buffalo Spinach	It is used for skin infections by the certain sections of the tribal people. It is also used as a laxative.
8	Water Cress	It is used in the traditional medicine system for the treatment of various ailments like leprosy, sore throat, ophthalmia, burns, pain and inflammation.
9	Orchid Tree	This plant has been known to possess antibacterial, antidiabetic, analgesic, anti-inflammatory, anti-diarrheal, anti-cancerous, nephroprotective and thyroid hormone regulating activity.
10	Punarnava	The plant is used as an emetic and purgative. The leaves are used against skin disease
11	Cork Swallow-Wort	The aqueous extract of the leaves are used against storage pest of food grains.
12	Horse Purslane	Decoction of the plant are given for fever, rheumatism, and as an antidote for alcohol poisoning
13	Creeping Woodsorrel	It is used as a hyper accumulator of copper. It can also be used for Phytoremediation
14	White Goosefoot	It is very useful in treating kidney stone and reducing the formation of stone. It is also used for inner and external swellings, jaundice, irregular period, curing infections after delivery, anemia and for blood purification.
15	Smooth Joyweed	It is used as a local medicine often in mixtures with other medicinal plants, to treat hepatitis, tight chest, bronchitis, asthma and other lung troubles.
16	Water Hyssop	It is now acknowledged as a nootropic, which is a “smart drug” that enhances brain function.
17	Small Knotweed	The crushed seeds are cooked and eaten as a remedy against constipation, stomach pain, and diarrhoea.
18	Chinese Fever Vine	Therapeutically, it is considered as an aphrodisiac. It improves

		strength and immunity, and is also useful in wound
19	Indian Chestnut Wine	It is having a long history in ethnomedicines for the treatment of many diseases such as menstrual disorders, rheumatic pain, bruises, gastralgia and other related diseases.
20	Headache Tree	It is used to treat inflammation, immune-related diseases, and stomach disorders, wound healing, and skin diseases.
21	Chekurmanis	Leaves are used as an antidiabetic, to treat ulcers, eye disease, and tonsillitis
22	Indian Cherry	Plant is well-known for its medicinal properties against variety of diseases, primarily hepatocellular disorders (Liver cancer).

Conclusion

Traditional leafy vegetables are characterized by limited research efforts, breeding efforts, germplasm characterization, knowledge of species distribution and production levels, and representation in ex-situ collections. A dearth of information and poor awareness may allow useful species to be overlooked through a vicious cycle of neglect and underutilization. Declining use and eroding knowledge of traditional vegetables have been observed in many places around the world, which threatens their persistence into the future and limits the delivery of their benefits to society. So, there is a need to identify the importance of leafy vegetables in terms of nutrition and food security, to ensure the characterization and conservation of traditional leafy vegetables and to achieve income and production sustainability.

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MOLECULAR MARKERS IN PLANT BREEDING

Article ID: AG-VO5-I06-110**G. S. Shai Prasanna¹, P. Sudha², D. Shoba³, and J. L. Joshi^{4*}**

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Abstract

Plant breeding has traditionally relied on phenotypic selection, which can be hindered by environmental influences, especially when targeting quantitative traits. Molecular markers offer a robust alternative by enabling indirect, genotype-based selection that enhances precision and efficiency. Their applications are vast, including germplasm conservation, genetic diversity analysis, varietal identification, marker-assisted selection (MAS), and genomic selection. Molecular markers have revolutionized the identification of hybrids and parental lines, particularly for traits with complex inheritance or those difficult to phenotype. In germplasm conservation, molecular markers assist in grouping accessions, detecting duplications, and managing genetic drift. For genetic diversity analysis, markers provide a clearer picture of underlying genetic relationships than phenotype-based methods, enabling accurate phylogenetic analysis through tools like dendrograms or principal component analysis. MAS enables selection for desired traits, such as disease resistance, at early growth stages or in off-season nurseries,

drastically reducing breeding cycles. Techniques like Marker-Assisted Backcrossing (MABC) and gene pyramiding have led to the development of improved varieties like ‘Improved Pusa Basmati 1’ and ‘Improved Sambha Mahsuri’. Furthermore, marker technologies support QTL introgression and Marker-Assisted Recurrent Selection (MARS), aiding in the accumulation of favorable alleles over successive generations. Genomic selection (GS) allows breeders to estimate Genomic Estimated Breeding Values (GEBVs) across the entire genome, facilitating selection without phenotyping. These advancements are supported by novel breeding schemes such as inbred enhancement, breeding by design, and advanced backcross QTL analysis. MAS has successfully led to the release of several improved crop varieties, particularly in rice and maize. As genomics advances and costs decrease, molecular marker technologies are expected to be increasingly integrated into mainstream breeding programs, bridging basic research with practical crop improvement.

Keywords: Marker-assisted selection, Genetic diversity, Genomic selection, QTL mapping, Marker-assisted backcrossing, Gene pyramiding,

Introduction

Breeders traditionally work with phenotypes, but environmental influence can reduce the effectiveness of breeding strategies, especially for quantitative traits. Molecular markers provide a way to rapidly and reliably identify genotypes indirectly by using linked markers. This has greatly facilitated breeding activities and enabled new approaches. The applications of molecular markers in plant breeding are numerous, including:

- Genetic diversity analysis
- Germplasm conservation
- Identification of varieties and hybrids
- Marker-assisted selection (MAS)
- Selection of parents for crosses
- Identification of heterosis loci
- Positional cloning of genes

Utilization of Molecular Markers in Plant Breeding

Genetic Diversity Analysis

Analyzing genetic diversity is crucial for understanding phylogenetic relationships and selecting parents for hybridization programs. While diversity analysis is often based on

phenotypes, this only reflects a portion of the actual genotypic variation. Molecular markers are considered more effective for capturing this genetic variation.

A common method to measure genetic distance is the modified Rogers distance. The resulting genetic distance estimates are used for phylogenetic analysis, which groups lines or individuals based on their genetic relatedness. A dendrogram is a common and easily understandable way to represent these phylogenetic relationships. Other methods include model-based approaches, principal component analysis, and principal coordinate analysis, with several software programs available for these analyses.

Germplasm Characterization and Conservation

Germplasm conservation is a critical and complex activity for crop improvement. Molecular markers can significantly assist in this process in several ways:

- **Genotyping accessions** to analyze diversity, group the accessions, and identify any gaps in the collection.
- **Identifying duplications** in the collection, which helps in removing redundant entries and reducing management costs.
- **Monitoring genetic changes** in heterogeneous accessions that may occur due to genetic drift or selection during procedures like regeneration.
- **Detecting associations** between markers and useful traits through association mapping if a large number of accessions are genotyped.
- **Introgression of useful genes** from unadapted germplasm into elite lines using the information from marker-trait associations.
- **Quick identification and retrieval** of specified accessions using their marker genotype data.

Identification of Varieties and Hybrids

Molecular markers can create unique DNA fingerprints for different plant individuals, lines, varieties, and hybrids. A DNA fingerprint is a profile composed of the genotypes of several molecular markers for a specific entity. SSR markers are widely used for this purpose.

These fingerprints allow for the unequivocal identification of different varieties and hybrids, which is useful for variety registration and plant breeder's rights (PBR). However, there can be some challenges, as some phenotypically uniform varieties may still show some genetic variation at the marker level.

Another key application is determining the **genetic purity of seed lots**. In hybrids, this involves checking the purity of parental lines and detecting contamination in the hybrid seed lot from other varieties, the male parent, or the female parent.

Selection of Parents for Hybridization

Choosing the right parents is the most critical step in a hybridization program. This selection is usually based on pedigree information and performance data. Molecular marker data can serve as a valuable supplement, especially for quantitative traits, because lines with similar phenotypes might possess different underlying Quantitative Trait Loci (QTLs).

Markers are also being explored to identify parental lines that will produce superior hybrids, a process that is currently costly and cumbersome. While predicting heterotic crosses with markers is still not fully reliable, marker data has been successful in assigning maize inbreds to their correct heterotic pools. The identification and mapping of heterosis loci (QTLs for heterosis) using markers may lead to new insights and more reliable prediction of heterosis in the future.

Positional Cloning

Positional cloning or map-based cloning, is a technique used to isolate and clone a gene for which only a mutant phenotype is known. The strategy involves these key steps:

1. Use the mutant allele to perform linkage mapping and identify two molecular markers that flank the gene.
2. Create a genomic library from the mutant's DNA using high-capacity vectors like YACs or BACs.
3. Screen the library with the flanking markers and use chromosome walking or jumping to isolate all the clones located between the markers, which should contain the target gene .
4. Use these clones to develop new, closer markers for high-resolution mapping with a large population to narrow down the genomic region containing the gene .
5. Sequence this region, identify potential genes, and confirm the function of the most likely candidate by transferring its non-mutant allele into the mutant strain to see if it restores the wild-type phenotype.

Marker-Assisted Selection (MAS)

Marker-assisted selection (MAS) is the process of indirectly selecting for a gene or QTL based on its linkage to a molecular marker. There are three main types of selection using MAS:

- **Foreground Selection:** The primary application, where breeders select for the target gene or QTL.
- **Background Selection:** Used in backcross programs to monitor and speed up the recovery of the recurrent parent's genome, excluding the target region from the donor parent.
- **Negative Selection:** Used to eliminate undesirable genes from a segregating population.

MAS is particularly advantageous when direct phenotypic evaluation is difficult, tedious, time-consuming, or destructive. In disease resistance breeding, MAS can substitute for problematic disease tests, reduce linkage drag, facilitate gene pyramiding, and allow for selection of QTLs for horizontal resistance. For MAS to be reliable, the markers should be tightly linked to the gene of interest; using markers that flank the gene on both sides enhances this reliability.

Marker-Assisted Back-Crossing (MABC)

Marker-assisted back-crossing (MABC) combines both foreground and background selection in a backcross program to transfer a gene/QTL from a donor to an elite recurrent parent. A proposed four-stage sampling strategy can accelerate the recovery of the recurrent parent genome to about 96% in just three backcross generations (BC3), saving significant time compared to conventional backcrossing which might require five or more generations (BC5).

A specific type of background selection called recombinant selection uses markers flanking the target gene to select for recombinants that contain only the target locus from the donor, minimizing the transfer of undesirable linked genes (linkage drag). MABC has been successfully used to transfer genes for traits that are difficult to phenotype, such as the *opaque-2* gene in maize, and to improve complex traits like yield by introgressing beneficial QTLs.

Gene Pyramiding

Gene pyramiding is the process of combining two or more distinct genes that govern a single trait, especially disease resistance, into a single line or variety. Conventional methods for pyramiding are cumbersome, requiring extensive progeny and disease testing. MAS greatly simplifies this by minimizing the need for these tests. For instance, MAS has been used to pyramid multiple genes for resistance to bacterial leaf blight (Xa4, xa5, xa13, Xa21) and blast (Pi1, Piz5, Pita) in rice, leading to varieties with broader and higher levels of resistance.

Bacterial Leaf Blight Resistant Version of “Pusa Basmati 1”

This section provides a detailed case study of developing 'Improved Pusa Basmati 1' (IPB1), the first variety in India created through MAS.

- **Objective:** To transfer two bacterial leaf blight resistance genes, *xa13* and *Xa21*, from the donor IRBB55 into the elite rice variety Pusa Basmati 1 (PB1).
- **Foreground Selection:** MAS was used to select for the two resistance genes, the *waxy* gene for grain quality, and the non-restorer allele for a CMS system. Specific markers like CAPS, STS, and STMS were used for this.
- **Background Selection:** A large number of polymorphic AFLP and STMS markers were used to select for plants with the highest recovery of the PB1 genome.
- **Breeding Scheme:** A limited backcross-pedigree scheme was used. After just one backcross (BC₁) and several generations of selfing and selection (F₂ to F₅), a line was identified with both resistance genes and over 86% recovery of the PB1 genome.
- **Outcome:** The resulting variety, IPB1, showed high resistance to bacterial leaf blight while retaining the desirable grain quality and agronomic traits of PB1. It even showed improvements, such as an erect flag leaf and reduced grain chalkiness. It yielded on par with or even higher than the original PB1.

This success story, along with others like 'Improved Sambha Mahsuri' and the QPM maize hybrid 'Vivek QPM9', demonstrates the power of MAS in crop improvement.

QTL Introgression

Molecular markers are highly effective for introgressing Quantitative Trait Loci (QTLs). For successful introgression, it is advisable to use at least three markers: one within the QTL and one on each flanking side. The QTLs selected for transfer should ideally be major QTLs that are expressed consistently across different environments.

However, a QTL's expression can be significantly affected by the new genetic background it is placed in. To address this, a combined selection approach is recommended, which integrates MAS for the QTL with traditional phenotypic selection for the trait. This approach helps ensure proper gene expression and allows for the accumulation of suitable genetic modifiers to minimize any negative pleiotropic effects of the transferred QTL.

Marker-Assisted Recurrent Selection (MARS)

Recurrent selection is a breeding method designed to accumulate favorable alleles for quantitative traits. Marker-assisted recurrent selection (MARS) is a scheme that uses molecular markers for indirect selection of these favorable QTL alleles.

The general procedure is as follows:

1. In an initial generation (e.g., F_2), plants are both phenotyped for the trait and genotyped for markers across the entire genome.
2. Multiple regression analysis is used to identify markers that are significantly associated with the desired trait.
3. A selection index is created based on both phenotype and the identified marker genotypes. Plants with the best index scores are selected and intermated.
4. In subsequent generations, selection is based solely on a marker index calculated from the genotypes of the pre-identified markers. Plants with the best marker index are intermated to form the next cycle. This process can be repeated for several generations, and since it doesn't require field-based phenotyping in every cycle, it can be done in greenhouses or off-season nurseries, allowing for 2-3 cycles of selection per year. This is much faster than conventional recurrent selection, which typically takes 2-3 years per cycle. MARS is now widely used by multinational seed companies.

Genomic Selection

Genomic selection (GS) is a breeding strategy based on molecular markers distributed over the entire genome, regardless of whether they are linked to a specific QTL. The key steps are:

1. A training population is established, which is related to the breeding population. This population is genotyped for a large number of markers and phenotyped for the target trait(s).
2. The genotype and phenotype data from the training population are used to estimate the effects of each individual marker on the target traits. These estimates are then used to compute genomic estimated breeding values (GEBVs) for all individuals in the population.
3. The breeding population, which will be used for selection, is then genotyped for the same set of markers.

4. The GEBVs for individuals in the breeding population are calculated based on the sum of the effects of all their marker alleles. Selection is then based solely on these GEBVs, with no phenotypic evaluation of the breeding population itself.

GS schemes have been developed for both cross- and self-pollinated species and have been used extensively and successfully in dairy cattle breeding. GS is an attractive and effective approach that is being applied for crop breeding as well.

Novel Breeding Schemes

Conventional breeding schemes were designed based on phenotype data and are not equipped to take full advantage of molecular marker technology. Several innovative breeding schemes have been proposed that integrate marker technology more deeply, including:

- **Inbred enhancement and QTL mapping:** Seeks to introgress QTLs from a suitable donor parent and simultaneously map these QTLs.
- **Advanced backcross QTL analysis:** Designed to facilitate the introgression of QTLs from unadapted germplasm into an elite line and simultaneously map them.
- **Single large-scale MAS:** Proposed to permit the development of elite lines that combine favorable alleles at the target loci present in elite germplasm.
- **Breeding by design:** This is the most ambitious scheme, aiming to develop plant types that have the desired alleles at all loci that are important for controlling all relevant traits. It involves (i) mapping all loci for all relevant traits, (ii) determining the markers associated with the desirable alleles, and (iii) using this information to construct the superior genotype *in silico* (computationally) using all available relevant loci. The predicted genotype would then have to be evaluated for its actual performance.

Advantages of Molecular Markers

1. **Simplicity and Objectivity:** MAS can be simpler, more objective, and sometimes non-destructive compared to phenotype-based selection, especially for traits like root characteristics.
2. **Increased Effectiveness:** Indirect selection increases the effectiveness of selection across different environments and avoids the confusing effects of the environment on the trait expression.

3. **Facilitates Difficult Selections:** They permit the pyramiding of disease resistance genes and allow screening for linked traits even at the seedling stage, which can be very difficult with conventional methods.
4. **Confident and Precise Selection:** Characters like disease resistance can be confidently selected for without needing pathogen inoculation. They also allow for the accurate determination of individual plant genotypes, enabling selection even in early generations.
5. **Accelerated Breeding:** Their use allows for selection in off-season nurseries and greenhouses, speeding up the breeding cycle. Indirect selection for QTLs is expected to require less time, space, and resources.
6. **Negative Selection:** They can be used for the elimination of undesirable traits.
7. **QTL Mapping:** Molecular markers make it possible to map quantitative trait loci (QTLs), which is not possible through conventional methods.

Limitations of Molecular Markers

1. **High Cost:** The cost of molecular markers is a significant limitation.
2. **Technical Requirements:** Using DNA markers requires a certain level of technical sophistication and expertise.
3. **Reproducibility Issues:** Some markers, like RAPD, are not always reproducible, although this can be resolved by converting them to more robust markers like SCARs.
4. **Development Effort:** Developing reliable markers like SSRs and STSs requires considerable and concerted effort and resources .
5. **Accuracy of QTL Mapping:** QTL mapping is affected by many factors, including the size of the mapping population and the number of locations used for phenotype determination. Therefore, linkage data based on a single experiment may not be accurate, and marker validation is required to determine the reliability of the markers for MAS .
6. **Marker Availability and Linkage:** Reliable, closely linked markers are not always available. Sometimes markers show linkage with the desirable allele in most lines but are linked with the undesirable allele in others .
7. **Genetic Background Effects:** The effectiveness and even the type of effect of a QTL can be markedly affected by the genetic background, which can limit the use of MAS for that QTL .

8. **QTL x Environment Interactions:** Significant interactions between QTLs and the environment also limit the usefulness of MAS for those QTLs .

In view of these limitations, a considerable discretion is necessary when selecting problems to be resolved by molecular markers. In many cases, conventional approaches are either ineffective or of doubtful effectiveness, making the use of markers warranted despite their high environmental influence on the traits of interest .

Achievements in MAS

Marker-assisted selection has been used to develop a large number of varieties in several countries. The first variety developed by MAS was a maize hybrid released in the U.S.A. for commercial cultivation in 2000. Perhaps the most remarkable application of MAS for biofortification is the development of orange-fleshed sweet potato rich in β -carotene.

In Indonesia, MAS has been used to develop the rice varieties 'Angke' and 'Condi', which are not only bacterial blight resistant but also yield ~20% higher than IR64, a popular variety of rice. Similarly, the Indian rice variety 'Improved Sambha Mahsuri' was developed by transferring three resistance genes into Sambha Mahsuri via MABC. 'Improved Pusa Basmati 1' was also obtained by introgressing two bacterial blight resistance genes into Pusa Basmati 1 using MABC. A major QTL, *Sub-1*, which specifies submergence tolerance, was transferred into the mega rice varieties Swarna and Sambha Mahsuri, resulting in the varieties Swarna-Sub 1 and Sambha Mahsuri-Sub 1, which have markedly improved submergence tolerance . MAS has also been used to improve quality traits, for example, by transferring the *opaque-2* gene into the parental inbreds of maize hybrid Vivek Hybrid Maize 9, leading to the hybrid Vivek QPM 9 which has comparable grain quality and yield but with improved lysine content.

Conclusion and Future Prospects

The use of molecular markers in plant breeding is expected to increase with time due to several factors:

- **DNA marker technology** is spreading rapidly, and vast amounts of data are being generated and stored in databases like 'Gramene' and 'GrainGenes'.
- **QTL mapping and MAS** can be combined with breeding, facilitating the conversion of basic research into an applied endeavor. MAS will be extremely effective in facilitating the transfer of transgenes by accurately tracking them in segregating generations.

- **Genomics research** is facilitating the discovery of SNPs located within genes, and the availability of ESTs (Expressed Sequence Tags) is generating data on SNPs located within genes, which is needed for mapping and marker validation.
- **High SNP markers** for candidate genes eliminate the need for mapping and marker genotyping platforms are available. SNP markers are rapidly gaining popularity due to their abundance, presence within candidate genes, and high detection platforms.
- **Multiplex PCR** allows for the evaluation of multiple marker loci in a single reaction, which reduces cost and saves considerable time.
- **Comparative mapping** may facilitate progress in QTL mapping between related species since it may be used to identify new syntenic markers in another related species.
- **Advances in high resolution mapping and genomics** will allow identification of sequences of genes that contribute to the target phenotypes. Markers based on such gene sequences will enhance the efficacy of MAS.
- **Availability of large numbers of useful markers** in public domains will encourage their use in MAS. Companies performing marker genotyping are coming up; this may permit cost-effective out-sourcing of this activity and relieve plant breeders to devote more time to plant breeding activities.
- However, the cost of MAS may remain the chief limiting factor till such time that innovations provide relatively cheaper MAS technologies, and modified breeding schemes further reduce the cost of MAS-based schemes vis-a-vis conventional breeding schemes.

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ROLE OF ETHYLENE INHIBITORS IN VEGETABLES

Article ID: AG-VO5-I06-111***Kaviya S and Dr.S.Haripriya**

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Introduction

Ethylene is a naturally occurring plant hormone that plays a critical role in regulating various physiological processes such as fruit ripening, leaf senescence, flower wilting, and abscission. While ethylene is essential for normal plant development, its uncontrolled action can lead to undesirable effects, particularly in post-harvest handling and storage of horticultural produce. To mitigate these effects, ethylene inhibitors are employed as chemical agents that either block ethylene biosynthesis or interfere with its action at the receptor level.

Ethylene inhibitors are especially significant in post-harvest management, where delaying ripening and senescence can substantially enhance the shelf life, quality, and marketability of fruits, vegetables, and ornamentals. Common ethylene inhibitors include compounds like 1-methylcyclopropene (1-MCP), silver thiosulfate (STS), and aminoethoxyvinylglycine (AVG). These inhibitors function by either binding to ethylene receptors, thus preventing signal transduction, or by inhibiting enzymes involved in ethylene synthesis. The use of ethylene inhibitors has become a vital component in modern post-harvest technology, offering a strategic approach to reduce losses, maintain produce freshness, and meet the demands of global supply chains. Ethylene is naturally occurring plant hormone which plays an important role in fruit ripening, senescence, postharvest physiology and interact with other hormones. Manipulation of ethylene concentration in plant we can play with shelf life of the produce.

ETHYLENE INHIBITORS

Inhibitors are chemical which inhibits activity of ethylene by reducing its production (via

blocking receptors, SAM, ACC synthase production).

EXAMPLES

- 2-aminoethoxyvinyl glycine (AVG)
- silver ions (Ag)
- gaseous compound 1-methylcyclopropene (1-MCP)
- maleic hydrazide MH
- STS

Inhibitor	Abbreviation	Site(s) of Action	Method of Application
2-Aminoethoxyvinyl glycine	AVG	ACC synthase	Liquid
2-Aminooxyacetic acid	AOA	ACC synthase	Liquid
Aminoisobutyric acid	AIB	ACC oxidase	Liquid
Cobalt ions	Co ²⁺	ACC oxidase	Liquid
1-Methylcyclopropene	1-MCP	Ethylene receptors	Gas
2,5-Norbornadiene	NBD	Ethylene receptors	Gas
Silver ions	Ag ⁺	Ethylene receptors	Liquid
Silver nitrate	AgNO ₃	Ethylene receptors	Liquid
Silver thiosulfate	STS	Ethylene receptors	Liquid
trans-Cyclooctene	TCO	Ethylene receptors	Gas

MECHANISM OF ACTION:

There are 3 steps where ethylene synthesis is inhibited.

1. Inhibition at biosynthesis level:

ACC formation is one of most limiting factor in ethylene biosynthesis. ACC formation is governed by 2 enzymes namely ACS AND ACO enzyme. Inhibitors prevent the formation of ACC.

■ ACS enzyme inhibitors:

aminoethoxy vinyl glycine (AVG) and aminoxy acetic acid (AOA)

■ ACO enzyme inhibitors- Co²⁺, α-amino isobutyric acid (AIB), and ethanol and acetaldehyde vapors

2. Competition by SAM:

Polyamines (PAs) such as putrescine (Put), spermidine (Spd), spermine (Spm) creates competition for SAM. No further formation ethylene.

3. At receptor level:

Compounds like 1-methylcyclopropene (1-MCP) has more affinity to ethylene receptors it binds to it there by prevent the ethylene synthesis.

Ethylene Biosynthesis and Signaling Pathway with Inhibitors

L-methionine (Met)

↓ (SAM synthetase)

S-adenosyl-L-methionine (SAM)

↓ (ACC synthase) — inhibited by 2-aminoethoxyvinyl glycine (AVG), 2-aminoxyacetic acid (AOA)

1-aminocyclopropane-1-carboxylic acid (ACC)

↓ (ACC oxidase) — inhibited by Cobalt ions (Co^{2+}), Aminoisobutyric acid (AIB)

Ethylene

↓ (receptors) — inhibited by Ag^+ , trans-cyclooctene (TCO), 1-methylcyclopropene (1-MCP), Norbornadiene (NBD)

CTR1

↓

EIN2

↓

EIN3/EIL1

↓

Responses

First we discuss about role of ethylene inhibitors in growth and development stage:

1.Maintaining Freshness and Texture:

Ethylene has effect on leaf growth and development. It cause softening, yellowing, and loss of crispness in vegetables like lettuce, carrots, and broccoli. By spraying of inhibitors it helps to maintain its freshness.

2.Reducing the flower drop:

When plants are subjected to water stress ethylene concentration increases which lead flower drop. Ethylene inhibitors help to reduce the flower drop.

3.Prevent ethylene induced disorder:

Excess of ethylene concentration causes yellowing in greens and bitterness in cucurbits.

4.Enhancement of Root and Shoot Growth:

High ethylene levels can inhibit root elongation and seedling growth. Inhibitors such as cobalt chloride (CoCl_2) and silver nitrate (AgNO_3) help promote better root and shoot development in crops like onions and carrots.

5.Stress Tolerance Improvement:

Ethylene is involved in stress responses, but excessive production can be harmful. Inhibitors help plants tolerate drought, salinity, and mechanical injuries better by controlling stress-induced ethylene production

6.Role of ethylene inhibitors in ripening at post harvest :

Ethylene plays a major role in ripening. Higher the concentration of ethylene causes the ripening .

7.Controlling Sprouting in Root Vegetables:

Potatoes, onions, and garlic sprout due to ethylene accumulation. Inhibitors like Maleic Hydrazide (MH) suppress unwanted sprouting.

EXAMPLES:

- ❑ **Tomatoes** at 0.01 ppm of 1-MCP delays tomato ripening by 8 days at 77°F (25°C).
- ❑ At 50°F (10°C), broccoli storage life was more than doubled by treatment with 1 ppm 1-MCP, while later experiments found that 1.00ppm 1-MCP was equally effective.
- ❑ **Silver nitrate at 500 mg/l** has been reported to be as effective as GA3 in inducing male flowers on gynoecious lines of cucumber.
- ❑ Muskmelon foliar sprays of Silver thiosulphate at 400 mg/l was found best for induction of male flower on gynoecious lines.

FUTURE SCOPE

When we find solution for ethylene inhibition completely we can reduce the export loss, increased shelf life and post harvest life .

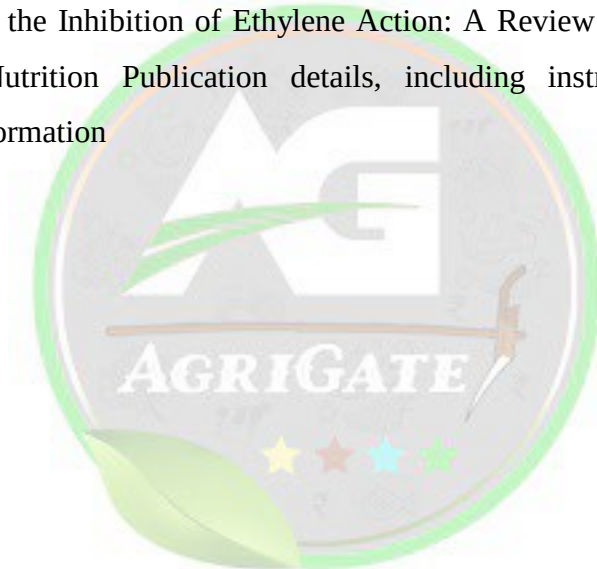


COMMERCIAL PRODUCTS:

- Aviglycine hydrochloride
- 1 MCP
- Aviglycine

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SOIL EROSION AND IT'S DSTRUCTIVE PHENOMENON

Article ID: AG-VO5-I06-112

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Introduction

The permissible limit of soil loss is generally considered to be 12 tons per hectare per year. But, The national average soil loss in india is estimated to be 21 tonnes per hectare per year, which is higher than the permissible limit of 12 t/ha/year. Approximately 0.666 grams of soil are lost every second per hectare in India. 30% of India's landmass is experiencing "minor" soil erosion, 3% facing "catastrophic" topsoil loss. Catastrophic erosion is defined as over 100 tonnes of soil lost per hectare annually. Brahmaputra Valley in Assam is identified as the country's biggest hotspot for soil erosion. It is estimated that by 2050 around 90 percent of the Earth's soils could be degraded. The loss of soil due to shifting agriculture (podo cultivation) is no less pronounced in India especially in north-eastern region. It has been estimated that more than 1.5 Mha of forest land is cleared for shifting agriculture every year. The total area affected by shifting cultivation is estimated to be 4.5 Mha. Shifting agriculture locally known as "jhumming".

Types of erosion

3. Natural Erosion or Geological Erosion - Erosion is termed as natural or geological erosion if the rate of soil loss does not exceed the rate of soil formation.
4. Accelerated Erosion - Once the rate of soil loss exceeds the rate of soil formation this type erosion is called accelerated erosion. The accelerated erosion is manmade mainly resulting from faulty agricultural practices and deforestation.

WIND EROSION

The wind erosion process may be divided into three simple but distinct phases i.e detachment, transportation and deposition.

- 1) Detachment: The lifting and abrasive action of the wind results in detachment of tiny soil grains from the aggregates or clods of which these are a part.
- 2) Transportation: Movement of detached particles takes place mainly by three processes saliation, suspension and surface creep.
 - i. Saltation- Movement of soil particles in a series of jumps or bounces. Soil particles having sizes ranging from 0.05 to 0.5 mm generally move in this process.
 - ii. Suspension- Suspension represents the floating of small sized particles in the air stream. Size of the soil particles In suspension process is less than 0.2mm in diameter.
 - iii. Surface creep-Rolling of coarse grains along the ground surface is called surface creep. Size of the soil particles in the surface creep is more than 0.5 mm.
- 3) Finally the material is eventually deposited in areas where the wind's velocity decreases or encounters an obstacle.

WATER EROSION

Splash Erosion:

Splash erosion or raindrop impact represents the first stage in the erosion process. Rain drops behave as little bombs when falling on exposed or bare soil, dispersing the soil aggregates and displacing the detached soil particles. The splashed particles may rise as high as 0.7 m above the ground and move horizontally to a distance of 1.5 m.

Sheet Erosion:

Sheet erosion is the uniform removal of soil layers from the sloping lands (skimming of the cream). The top fertile soil layer is washed away from the arable lands. Since a uniform layer of soil is removed, this type of soil erosion mostly goes unnoticed by the farmers.

Rill Erosion

Rill erosion is the most common form of soil erosion by water. When the runoff water gets concentrated due to isolated patches of vegetation or rockpieces, the silt-laden runoff forms well-defined small ephemeral channels called rills. The rills so formed from one storm are often obliterated before the next storm by simple tillage practices.

Gully Erosion

Gully erosion is an advanced stage of rill erosion where surface channels have eroded to the point where these cannot be obliterated by tillage operations.



SOIL CONSERVATION PRACTICES

Soil conservation refers to the practices and strategies implemented to prevent soil erosion, maintain soil fertility, and ensure a healthy soil ecosystem. It's about managing the soil to prevent its destruction or degradation.

CONSERVATION TILLAGE

Conservation tillage is an agro management method that seeks to reduce the intensity or frequency of tillage operations in order to realize both environmental and economic benefits. It involves the planting, growing and harvesting of crops with limited disturbance to the soil surface. Two types 1) No tillage 2) Minimum tillage

CHECK DAMS
A check dam is a small dam constructed across a drainage ditch, swale, or channel to lower the velocity of flow. Reduced runoff velocity reduces erosion and gullyng in the channel and allows sediments to settle out. A check dam may be built from stone, sandbags filled with pea gravel, or logs.

VEGETATIVE BARRIERS

Vegetative barrier is a strip planted with a grass or shrub that runs across the slope. It slows down water flowing down the slope and catches the sediment that has been eroded uphill. Over time, soil may build up behind the strip.

COVER CROPS

Cover crops are close-growing crops such as grasses, legumes or small grains that are grown primarily to provide seasonal protection against erosion and for soil improvement.

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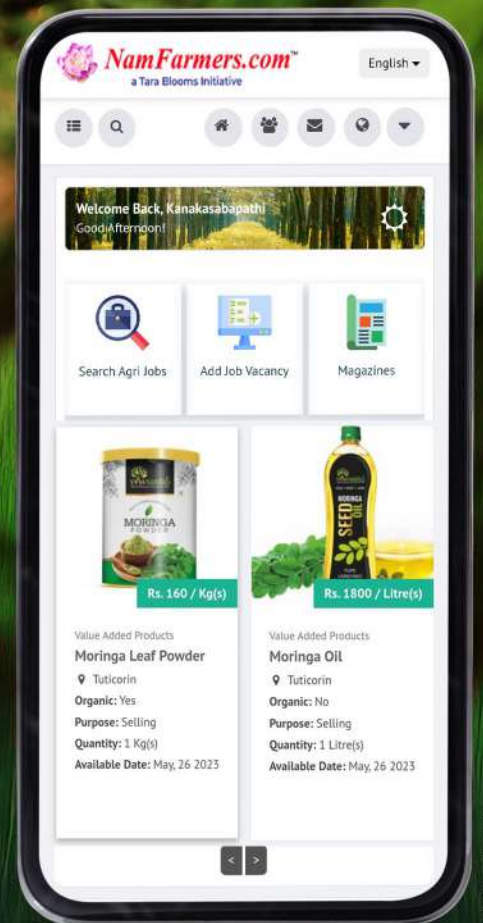
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