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From the Desk of Editor-in-chief

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I would like to introduce the launch of “**AgriGate - An International Multidisciplinary Monthly e-Magazine Volume 05 Issue No. 05 – May 2025**” with immense pleasure. Our team is privileged to dedicate this issue to **Agricultural Labour**. International Labour Day 2025: Every year on May 1, countries around the world observe **International Labour Day**, also known as International Workers' Day, to honour the hard work and contributions of workers across industries and Farming sectors. **International Day for Biological Diversity** is also observed on 22 May every year to increase awareness and understanding of the issues of biodiversity.

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
AgriGate Magazine

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BEYOND HEAT: ADVANCED NON-THERMAL TECHNIQUES FOR FRUIT AND VEGETABLE PRESERVATION

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Abstract

The demand for high-quality, fresh produce with extended shelf life has driven the exploration of non-thermal processing techniques for fruit and vegetable preservation. Traditional thermal methods, such as heat treatment and pasteurization, while effective in controlling microbial growth and preserving nutritional value, often result in undesirable changes in texture, color, and flavor. Non-thermal technologies offer a promising alternative by preserving the sensory and nutritional qualities of produce while ensuring safety and extending shelf life. Techniques such as high-pressure processing, ultraviolet light treatment, pulsed electric fields, and ozone treatment have shown considerable potential in maintaining the freshness of fruits and vegetables. These methods work by inactivating microorganisms, enzymes, and pathogens without the use of heat, minimizing the degradation of vitamins, antioxidants, and other beneficial compounds. The present article highlights the latest advancements in non-thermal processing, discusses their mechanisms, advantages, and challenges, and examines their application in the food industry. By embracing these innovative approaches, the food industry can achieve more sustainable and effective preservation of fruits and vegetables, meeting consumer demand for healthier, minimally processed foods.

Keywords: Non-thermal techniques, preservation, fruits, vegetables, etc.

Introduction

The preservation of fruits and vegetables is a critical challenge in the global food industry, aiming to balance food safety, nutritional retention, and sensory quality. Traditional

preservation methods, primarily involving thermal treatments such as pasteurization and canning, have been widely used to extend shelf life. However, these methods often lead to undesirable effects on the texture, flavor, and nutritional content of the produce, such as the degradation of vitamins and antioxidants (Cano-Lamadrid & Artés-Hernández, 2022). As consumers increasingly demand fresh, minimally processed foods, there is a growing need for alternative preservation techniques that do not compromise the quality of fruits and vegetables.

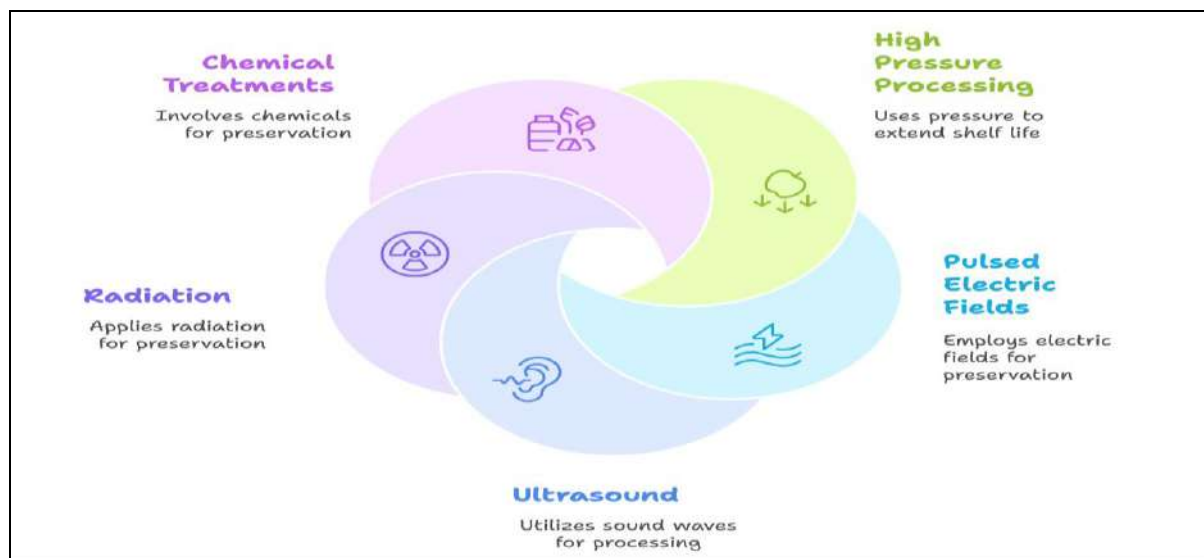


Figure 1: Overview of non-thermal techniques employed for preservation of fruit and vegetables

In response to these challenges, non-thermal processing technologies have emerged as viable alternatives, offering the potential to preserve the natural characteristics of produce while ensuring safety and extending shelf life. Non-thermal techniques, such as high-pressure processing (HPP), ultraviolet (UV) light treatment, pulsed electric fields (PEF), and ozone treatment, operate by inactivating microorganisms, enzymes, and pathogens without the use of heat (Allai et al., 2023). These methods have shown promising results in preserving the sensory qualities, such as texture, color, and flavor, while maintaining the nutritional profile of fruits and vegetables (Safwa et al., 2023). Among these techniques, HPP has gained significant attention for its ability to extend shelf life without significantly altering the product's original characteristics (Nabi et al., 2021). Similarly, UV light and PEF have demonstrated effectiveness in reducing microbial load while preserving vitamins and antioxidants (Ghoshal, 2023). Furthermore, the use of ozone as a disinfectant has been shown to enhance the shelf life of fresh

produce by controlling microbial contamination (Barthwal et al., 2025). This article explores the latest advancements in non-thermal preservation technologies, highlighting their mechanisms, advantages, challenges, and potential applications in the food industry. By embracing these innovative techniques, the food sector can meet the rising consumer demand for healthier, more sustainable food preservation methods.

High pressure processing

High-Pressure Processing (HPP) is a non-thermal food preservation technology that extends the shelf life of fruits and vegetables while maintaining their nutritional value, flavor, and texture. HPP involves applying hydrostatic pressure (300–600 MPa) to food products, effectively inactivating microorganisms without using heat. This method is gaining popularity due to its ability to preserve bioactive compounds and fresh-like sensory attributes.

HPP disrupts the cellular structures of microorganisms and enzymes, preventing spoilage while retaining essential nutrients. Unlike thermal treatments, HPP does not degrade heat-sensitive compounds such as Vitamin C, carotenoids, and polyphenols, making it ideal for health-focused food products (Wu et al., 2022). HPP is widely used in the preservation of fruit juices, ready-to-eat salads, and smoothies. It maintains the natural texture and color of fresh produce, making it a preferred method for premium food products (Song et al., 2022). However, the high cost of HPP equipment is a significant limitation, restricting its adoption by small-scale producers. Additionally, while HPP effectively reduces microbial load, it may not eliminate all pathogens, particularly in high-fat or high-sugar foods (Osaili et al., 2025). Some delicate fruits, such as strawberries and leafy greens, may also experience undesirable texture changes due to pressure application (Gidado et al., 2024).

Research is exploring hybrid approaches, such as combining HPP with antimicrobial agents and mild heat, to enhance its effectiveness (Rajendran et al., 2022). Advances in pressure distribution technology and controlled atmosphere packaging are also being investigated to improve consistency and efficiency (Pou & Raghavan, 2020). While HPP offers significant benefits, optimizing its application and integrating it with other preservation techniques is crucial for its broader adoption in the food industry.

Pulsed Electric Fields (PEF)

Pulsed Electric Fields (PEF) is a non-thermal preservation technique that extends the shelf life of fruits and vegetables while maintaining their nutritional and sensory quality. By

applying short bursts of high-voltage electricity (10–80 kV/cm), PEF induces electroporation in microbial and plant cell membranes, leading to enhanced microbial inactivation and improved preservation (Jin & Zhang, 2020). PEF treatment disrupts cellular integrity by creating pores in the membrane, increasing permeability and enhancing mass transfer. This mechanism is particularly beneficial for accelerating drying, freezing, and juice extraction processes. Research has shown that PEF-treated onions experience a 30% reduction in drying time, improving energy efficiency in food processing. Similarly, PEF improves the texture of frozen and thawed produce, such as carrots, by maintaining cellular structure (Ghoshal, 2023).

PEF is also effective in microbial control, significantly reducing spoilage organisms in fresh-cut fruits and extending their shelf life. PEF-treated fruit juices retain higher antioxidant content and better sensory attributes compared to thermally processed alternatives, with shelf-life extensions of up to 25 days (Lytras et al., 2024). Despite its advantages, PEF requires optimization for different food matrices, as the effectiveness depends on electric field strength, pulse duration, and specific produce characteristics (Nowosad et al., 2020). High equipment costs remain a barrier for small-scale producers, and further studies are needed to assess long-term impacts on nutritional and sensory properties. PEF presents a sustainable alternative for fruit and vegetable preservation, but future advancements in cost-effective systems and hybrid preservation approaches could enhance its industrial adoption.

Ultraviolet (UV) Irradiation

Ultraviolet (UV) irradiation, particularly UV-C (100–280 nm), is an effective non-thermal preservation method that extends the shelf life of fruits and vegetables while maintaining their nutritional properties. It primarily works by damaging microbial DNA, preventing replication, and reducing spoilage. Additionally, UV treatment induces stress responses in plant tissues, leading to the accumulation of bioactive compounds such as phenolics and antioxidants (Emus-Medina et al., 2023). UV-C irradiation is widely used for microbial inactivation on fresh produce surfaces, reducing postharvest diseases caused by fungi and bacteria (Rivas et al., 2023). Research shows that UV treatment effectively controls *Botrytis cinerea* on strawberries and *Alternaria alternata* on mangoes. Moreover, UV exposure stimulates the production of beneficial phytochemicals, enhancing antioxidant activity in fruits and vegetables (Darré et al., 2022). Another key benefit of UV treatment is its ability to slow down ripening and senescence by modulating enzymes such as polygalacturonase and pectin methyl esterase. This helps

maintain fruit firmness and prolongs freshness (Kan et al., 2025). Despite its advantages, UV irradiation has limitations. Its low penetration depth means its effects are primarily restricted to the surface, requiring uniform exposure, which can be challenging for irregularly shaped produce (Darré et al., 2022). Additionally, UV treatment lacks residual antimicrobial effects, making post-treatment handling crucial to avoid recontamination (Werkneh & Islam, 2023). Excessive UV exposure may also cause discoloration and texture degradation, emphasizing the need for precise optimization (Darré et al., 2022). UV irradiation is a promising, eco-friendly preservation method, but further research is needed to refine its application and enhance its effectiveness for various types of produce.

Table 1: Non-thermal techniques for fruit and vegetable preservation: working principle, mechanism along with merits and demerits.

Technique	Working Principle	Mechanism	Advantage	Disadvantage
High-Pressure Processing (HPP)	Uses high pressure (300–600 MPa) to inactivate microorganisms and enzymes, preserving the quality of food.	Pressure is applied uniformly to destroy microorganisms and enzymes without the need for heat.	Retains nutritional quality, taste, and texture; extends shelf-life.	High equipment cost; potential textural changes in some products.
Ultraviolet Light (UV) Treatment	Uses UV light (wavelength of 200–280 nm) to kill or inactivate microorganisms on the surface of food.	UV light damages DNA/RNA of microorganisms, preventing reproduction.	Does not require chemicals; easy to apply to liquid foods; preserves sensory attributes.	Limited penetration depth; effectiveness depends on surface cleanliness.
Pulsed Electric	Applies short	Causes pore	Retains	Requires

Fields (PEF)	bursts of high-voltage electric fields to food to induce electroporation of cell membranes.	formation in microbial cell membranes and plant tissues.	nutritional and sensory qualities; minimal heat generation.	uniformity of electric field distribution; costly technology.
Ozone Treatment	Ozone (O ₃) gas is applied to food to inactivate microorganisms and degrade contaminants.	Ozone oxidizes cell membranes, proteins, and enzymes, leading to microbial inactivation.	Effective against a wide range of pathogens; reduces chemical preservatives.	Potential damage to food quality (color, flavor); limited penetration.

Pulsed Light (PL)

Pulsed Light (PL) technology is a non-thermal food preservation technique that utilizes high-intensity, short-duration pulses of broad-spectrum light (UV to near-infrared) to inactivate microorganisms on fruit and vegetable surfaces. Microbial destruction is primarily attributed to mechanisms such as photochemical, photothermal, and photophysical effects (Mandal et al., 2020). This method enhances food safety and shelf life while preserving nutritional and sensory qualities. PL technology operates by emitting high-intensity light pulses, typically lasting microseconds to milliseconds, which deliver significant energy to microbial cells (Oms-Oliu et al., 2010). The UV-C component (200–280 nm) damages microbial DNA and RNA, leading to pathogen inactivation. Additionally, the rapid absorption of light energy can cause localized heating and photochemical reactions that further contribute to microbial reduction.

Studies have shown PL's effectiveness in reducing microbial loads on fresh produce. For example, it significantly inactivates *Escherichia coli* and *Listeria monocytogenes* on lettuce and tomatoes, reducing foodborne illness risks (Ashrafudoulla et al., 2023). Furthermore, PL delays ripening and reduces spoilage in strawberries and blueberries, extending shelf life (Cao et al., 2017). Its potential in maintaining nutritional integrity and inhibiting enzymatic browning in

minimally processed fruits has also been demonstrated. Despite its advantages, PL technology has limitations. Its effectiveness is primarily limited to surface decontamination due to low penetration depth (Oms-Oliu et al., 2010). Microorganisms beneath the surface may remain unaffected, necessitating complementary preservation methods. Furthermore, optimization of PL intensity and duration is crucial to prevent undesirable effects such as discoloration and textural changes in sensitive produce (Mandal et al., 2020). The scalability and economic feasibility of PL remain areas of ongoing research for widespread commercial adoption.

Pulsed Light technology presents a promising non-thermal preservation approach for fruits and vegetables, effectively inactivating surface microorganisms and extending shelf life while maintaining product quality. However, addressing its limitations through research and technological advancements is essential for its broader application in the food industry.

Ultrasound (US)

Ultrasound (US) technology has become a promising non-thermal method for preserving fruits and vegetables. It offers several advantages, including shorter processing times and minimal impact on the nutritional and sensory qualities of food (Onyeaka et al., 2023). Ultrasound works by emitting high-frequency sound waves, typically above 20 kHz, which generate mechanical vibrations within the food matrix. These vibrations create microbubbles that implode, generating localized high temperatures and pressures in a process known as acoustic cavitation. This phenomenon disrupts microbial cell walls, inactivates enzymes responsible for spoilage, and extends shelf life. Ultrasound effectively reduces microbial populations on the surfaces of fruits and vegetables, enhancing food safety without the need for chemical preservatives. When combined with osmotic dehydration, ultrasound accelerates water removal from fruits and vegetables, improving texture and reducing energy consumption in drying processes (Salehi, 2023). Ultrasound treatment can deactivate enzymes like polyphenol oxidase and peroxidase, which cause browning and quality degradation in fruits (Sui et al., 2023). Although ultrasound presents several benefits, its effectiveness depends on factors such as frequency, intensity, and treatment duration (Bhargava et al., 2021). Optimizing these parameters is crucial to avoid negative impacts on food quality, such as texture changes and nutrient loss. Additionally, ultrasound's penetration depth is limited, meaning it is most effective for surface treatments. As a result, further research is required to optimize the technology and expand its industrial applications (Artés-Hernández et al., 2017). Ultrasound technology offers a viable non-

thermal preservation method for fruits and vegetables, providing benefits like microbial decontamination, enhanced dehydration, and enzyme inactivation. However, careful optimization of treatment parameters is necessary to maintain product quality (Artés-Hernández et al., 2017).

Cold Plasma (CP)

Cold Plasma is emerging as a promising non-thermal preservation technology for fruits and vegetables. It offers multiple advantages, including microbial decontamination, enzyme inactivation, and extended shelf life with minimal impact on nutritional and sensory properties (Singh & Thakur, 2024). Cold Plasma is generated by applying a high voltage to a gas, producing highly reactive species such as electrons, ions, and radicals. These reactive species interact with microbial cells, disrupting cell membranes, damaging DNA, and leading to microbial inactivation (Yawut et al., 2024). Additionally, CP can deactivate spoilage enzymes like peroxidase and polyphenol oxidase, which are responsible for the deterioration of color and texture in fruits and vegetables (Harikrishna et al., 2023). Cold Plasma is effective in reducing microbial populations on the surface of fruits and vegetables, ensuring better food safety without the need for chemical preservatives (Harikrishna et al., 2023). CP treatment can deactivate enzymes that cause browning and quality loss, including polyphenol oxidase and peroxidase, which are critical in maintaining the visual and sensory attributes of fresh produce (Illera et al., 2019). Studies indicate that CP treatment can preserve the texture, color, and nutritional content of fruits and vegetables while extending shelf life, making it an ideal solution for postharvest handling (Artés-Hernández et al., 2017). While Cold Plasma shows great potential, its effectiveness depends on several factors such as plasma power, treatment time, gas composition, and the specific properties of the produce. Prolonged exposure to CP can result in undesired changes in texture and nutrient levels. Therefore, optimizing treatment parameters is essential to ensure a balance between microbial inactivation and quality preservation. Cold Plasma technology offers a promising method for the preservation of fruits and vegetables, providing microbial decontamination and quality maintenance. However, further optimization and research are necessary to maximize its industrial applications (Hernández-Torres et al., 2022).

Ozone Treatment

Ozone (O₃) is increasingly being used in the preservation of fruits and vegetables due to its powerful oxidizing properties. It is primarily employed for microbial decontamination, extending shelf life, and maintaining quality attributes such as texture, color, and nutritional

content (Botondi et al., 2021). Ozone works through its strong oxidative capabilities, generating reactive oxygen species (ROS) such as hydroxyl radicals and singlet oxygen. These reactive species interact with the microbial cell walls, to cell lysis and deactivation. Ozone also inhibits enzymes responsible for spoilage, such as polyphenol oxidase and peroxidase, reducing browning and degradation of quality. Additionally, ozone exposure activates plant defence mechanisms, reducing oxidative stress and preserving the quality of produce (Artés-Hernández et al., 2017). Ozone is highly effective in reducing microbial populations, such as bacteria, yeasts, and molds, on the surface of fresh produce. This reduces the risk of contamination and improves food safety without the need for chemical sanitizers (Artés-Hernández et al., 2017). Ozone treatment prolongs the shelf life of fruits and vegetables by inhibiting microbial growth and enzymatic reactions that cause spoilage (Botondi et al., 2021). It has been shown to effectively reduce spoilage and extend freshness in a range of produce, including leafy greens and tomatoes (Smetanska et al., 2013). Studies indicate that ozone treatment helps preserve the textural integrity and nutritional quality of fruits and vegetables. For example, it can reduce browning in fresh-cut produce and help maintain the firmness and color of fruits like tomatoes (Iturralde-García et al., 2022). While ozone treatment is promising, it requires careful control of factors like concentration, exposure time, and temperature. Excessive ozone exposure may lead to oxidative damage and undesirable effects on the quality of the produce (Smetanska et al., 2013). Optimizing these parameters is essential to maximize its effectiveness without compromising the quality of the food. Ozone treatment is a promising technology for non-thermal preservation of fruits and vegetables, providing microbial decontamination, shelf-life extension, and quality preservation. However, careful control over ozone exposure is required to prevent adverse effects and ensure optimal preservation (Botondi et al., 2021).

Conclusion

Advanced non-thermal techniques, such as high-pressure processing, cold plasma, ozone treatment, pulsed electric fields, and ultrasound, offer effective alternatives to traditional heat-based preservation methods. These techniques work by inactivating pathogens and spoilage enzymes while preserving the nutritional and sensory quality of fruits and vegetables. Technologies like ozone and cold plasma have demonstrated benefits in microbial reduction and quality maintenance. However, challenges remain in optimizing treatment parameters and

ensuring regulatory compliance. Continued research is crucial to fully realize the potential of these non-thermal preservation methods in enhancing food safety and quality.

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TIPS FOR CURTAILING PADDY CULTIVATION COSTS

Article ID: AG-VO5-I05-02

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Introduction

There are many instances of unnecessary cultivation costs in paddy and basmati that must be eliminated in order to increase net profit. Several important tips for lowering cultivation costs in paddy and basmati are discussed below:

Sort duration varieties:

To conserve depleting underground water, the recommended short duration varieties are the best choice. These are resistant to the majority of Bacterial Leaf Blight races. Short duration varieties require 15–25% fewer irrigations than long duration varieties like Pusa 44 while providing comparable net returns due to pesticide and labour savings.

Leveled fields:

The land should be precisely levelled using laser land leveler and this operation should be repeated every three years. It ensures uniform water stagnation throughout the field and conserves between 20-25% of irrigation water compared to an unleveled field. Additionally, levelled fields improve the efficacy of herbicides applied.

Avoid paddy cultivation in sandy/light textured soils:

Avoid cultivating paddy in sandy or light textured soils due to their low water retention capacity. Iron deficiency is much more likely to occur in paddy/basmati soils than in heavy soils. Herbicide efficacy is also reduced because water does not stagnate for the required 48 hours due to the increased infiltration rate. Paddy cultivation on these soils is costly and yields are low. Therefore, the crops that require less water must be grown in sandy soils.

Don't grow paddy with brackish water:

Due to the certainty of paddy marketing at MSP, farmers have begun cultivating it even in the areas having brackish underground water. It is a very dangerous trend for the state's agricultural sustainability. Farmers cannot expect to earn a profit from crops grown in low-quality water.

Seed treatment:

Treat seed and seedlings prior to sowing/transplanting to control seed-borne diseases in paddy/basmati. Around half of the diseases spread via seed are not treatable later, but they can result in significant yield loss. The cost of seed treatment however is meager.

Maintain optimum plant population:

During the surveys, up to 17-22 plants per square metre were observed, compared to the recommended 33 plants per square metre for paddy/basmati. To maximize yield, the number of plants per square metre must be increased. Additional labour costs of up to Rs. 500/- per acre are acceptable for this purpose. Additionally, mechanical transplantation of paddy can be attempted using a growing mat type nursery.

Apply need based fertilizers:

It is a myth that increased fertilizer use results in increased yields. Excessive fertilizer use attracts insects and diseases. Fertilizer should be applied based on a soil test. Reduce nitrogen application by 50% if paddy is followed by green manure. Reduce the nitrogen dose by 2 kg (4.35 kg Urea) and the phosphorous dose by one kg (2.17 kg DAP) for each tonne of FYM applied. If the recommended dose of phosphorous (25 kg per acre) has been applied to the preceding wheat crop, phosphorous application to paddy/basmati can be omitted. Excessive phosphorus use may result in phosphorus-induced zinc deficiency. To address this issue, a higher amount of zinc sulphate needs to be applied which further increases the cost of cultivation.

Judicious use of irrigation water:

Continuous water ponding in paddy fields from the day of transplantation until the crop matures is a common practice with the intention of increasing yield. Farmers normally apply 25-35 irrigations over the whole crop period. The water must be kept standing in paddy fields for the first 15 days after transplanting. After two days of infiltration of already standing water, irrigate the crop. This can reduce irrigation water consumption by up to 20-25 percent. Irrigation should

be stopped 15 days prior to crop harvesting. This practice not only saves cost of irrigation, but also helps preserve nature's most precious gift to mankind.

Use of weedicides:

Each year, try to change the group of weedicides used. Always adhere to the adage "Recommended dose of recommended weedicide applied at the recommended time." If we miss one of these three, we may have to apply more weedicides to control the weeds, increasing the cost of cultivation.

Use need based pesticides:

Not only does blanket application of insecticides increase cultivation costs, but it also contributes to atmospheric pollution. Economic Threshold Levels (ETL) for insecticide application must be adhered to minimize insecticide use. The recommended ETL for leaf folder control is 10%, for stem borer control is 5% in parmal paddy and 2% in basmati, and for hoppers control is a minimum of 5 plant hoppers per hill. Therefore, conduct regular crop surveys and apply the crop with recommended insecticides/pesticides as soon as insect pests cross the ETL. Pesticide use below these levels results in economic loss by increasing the cost of cultivation.

Record keeping:

Maintaining accurate records is critical to curtail cultivation costs. Farmers are incapable of recalling all expenses and receipts verbally. However, a written record can be verified at any point in time. The farmer can make comparisons with other farmers and thus avoid incurring additional unnecessary costs in the future.

Marketing:

Harvest only the matured crop to avoid wasting time drying out the produce in the market. Farmers are only required to pay two marketing charges at the market (unloading and cleaning of the produce). Both of these operations can be accomplished at the farm level through the use of permanent hired labour or family labour, thereby avoiding these charges. Additionally, unloading produce from trolleys using hydraulic jacks at the grain market can save the unloading charges. Basmati market prices fluctuate according to time and location.

Market the produce after conducting a thorough market survey and determine the best location for a higher price while keeping transportation costs in mind. The farmer should remain present during the auction/selling. If the farmer has a doubt of some malpractice in the weighing of the produce, he may complain in the market committee and can recheck the



weighting of 10% of his produce without incurring any costs. If any malpractice is established, the appropriate action may be taken against the responsible party. Farmers may follow the aforementioned tips to maintain the quality of their produce while also lowering cultivation costs of paddy/basmati, thereby increasing their net margin.

EFFECT OF GRAFTING TECHNOLOGY ON BRINJAL CROP TO CONTROL SOIL BORN DISEASE, IMPROVE YIELD AND QUALITY OF FRUITS UNDER OPEN FIELD CULTIVATION CONDITION**Article ID: AG-VO5-I05-03*****¹Mr. Yashwant L. Jagdale and ²Dr. Dheeraj Shinde**

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Introduction

Baramati is drought prone area, where the average rainfall received is about 400-450 mm. As there are water scarcity and soil borne diseases problem, most of the farmers uses the raised bed with or without mulching paper and regular seedlings for plantation. Although the Production of Brinjal is not better. So, for increasing the production and reduction of percentage of soil borne diseases infestation trial was carried out at different villages of Pune District.

Intervention of KVK

KVK Baramati introduce the Vegetables Grafting Technology to examine the effect of grafted seedlings of open field Brinjal (*Solanum Melongena*) family – *Solanaceae* for controlling the soil borne disease problem and improving yield and quality of Brinjal. Brinjal cultivars, Vishal were grafted on *Solanum Torvum* (ST) rootstocks that are known to be tolerant to soil borne diseases. In the second treatment Brinjal Cultivar Vishal grafted on wild local rootstock & Non-grafted Brinjal was used as controls. Transplanting was done on raised bed.

Output:

Trial was carried out by KVK, Baramati during the year 2022-2023 & 2023-2024. Total 20 trials were conducted in two tehsils of Pune districts. Also, technical leaflet was developed on grafting techniques. News article & farmers Training manual was published and Method Demonstrations was conducted on Grafting technology in the Brinjal.

Large Scale Impact/ Horizontal Dissemination

The effect on Grafting Technology in Brinjal to control soil born disease, improve yield

and quality of fruits under Open field Cultivation condition this technology is very useful to reducing soil borne diseases problem and for improving fruit quality, yield increase by 31.21 % and receiving maximum net returns to the farmers with increasing crop duration by 55 days.

By observing the result of this technology now days approx.352 farmers of Brinjal with covering a total area 110.5 ha in four tehsils i.e. Baramati, Purandar, Daund, Indapur of Pune districts also in the Nashik district, farmers adopted this technology. KVK, Baramati Provided training of Vegetables Grafting Technology to the different areas of Nurserymans. Now a days total 4 Nurseries in Nashik, Palghar & Latur started the Production of vegetables grafting seedlings under the guidance of KVK and generating more income.

Awards and Achievements: NABARD, Pune has given recognition to this Vegetables Grafting Technology as a Best Technology for doubling the farmers Income.



Recognition received from NABARD, Pune as a Best Technology	Grafting article published in Agro-Won News Paper	Trials Conducted on the Farmers Field

Outcome of the intervention:

Performance of the Technology with performance indicators	T1- Check / Control Local	T2- Assessment (RT- ST)	T3- Assessment (RT- Local)
Yield per hectare	362 q /ha	475 q/ha	412 q/ha
% yield increase	Nil	31.21 %	13.81
% of soil borne diseases	14 %	1 %	7.5%
Crop Duration increase in days	Nil	55 days	30 days
Net Returns (Rs /ha)-	Rs.115700	Rs.227500/-	Rs. 1,36,700/-
C: B Ratio	1: 1.4	1: 2.5	1: 1.5

SOWING THE DIGITAL FUTURE: EMPOWERING FARMERS THROUGH INNOVATIVE AGRICULTURAL PRACTICES

Article ID: AG-VO5-I05-04**Tummala Naga Satya Sai Srivani¹ and Gandham Aditya²**¹Ph.D research scholar, JAU, Junagadh, Gujarat, 362001.²Assistant professor, Dept. of Horticulture, SKCAS, Ananthapuramu, A.P. 515002.

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Introduction

"Digital agriculture" is often seen as a transformative solution to persistent challenges faced by farmers. It refers to the integration of Information and Communication Technology (ICT) and data ecosystems to support the development and delivery of timely, targeted information and services. This approach aims to make farming more profitable, sustainable, and efficient while ensuring the production of safe, nutritious, and affordable food for all (ICRISAT, 2016). The use of big data in food production, combined with technologies such as the Internet of Things (IoT), blockchain, artificial intelligence (AI), machine learning, cloud computing, unmanned aerial vehicles (UAVs), and robotics, collectively contribute to what is now known as "digital agriculture."

Benefits of Digital Agriculture

- **Increased agricultural productivity** through the adoption of modern farming practices
- **Prevention of soil degradation**, e.g., mitigating the impact of flooding
- **Reduction in chemical usage** for crop production
- **Efficient and economical utilization of water resources**
- **Improved crop quality and quantity** while reducing production costs
- **Development of a positive attitude** among farmers towards agriculture
- **Enhancement of farmers' socioeconomic status**

Major Digital Technologies Used in Agriculture

1. Internet of Things (IoT) & Smart Sensors
2. Unmanned Aerial Vehicles (UAVs)
3. Artificial Intelligence (AI)
4. Robotics

1) IoT & Smart Sensors

IoT and smart sensors play a crucial role in collecting real-time data. Data analytics helps farmers make informed decisions regarding harvest time, disease risks, production volume, and environmental factors.

Types of Sensors in Agriculture

These sensors, installed in weather stations, drones, and robots, can be controlled via mobile applications, helping farmers monitor and optimize their crops efficiently.

- **Optical Sensors:** Measure soil properties such as clay content, organic matter, and moisture. Mounted on vehicles or drones, they analyze soil reflectance and plant color.
- **Electrochemical Sensors:** Detect soil nutrients by sensing ions like nitrate, potassium, and hydrogen.
- **Dielectric Sensors:** Monitor soil moisture levels, particularly when vegetation is sparse.
- **Electronic Sensors:** Installed on tractors and field equipment to track operations and provide real-time updates to farm managers via email.



Representational image: This shows that there are many sensors integrated into a single device that is finally installed at the farm.

2) Unmanned Aerial Vehicles (UAVs)

Drones, also known as UAVs, are remotely operated or autonomous aircraft that enhance agricultural practices. They are used for aerial imaging, crop monitoring, spraying, and precision farming applications.

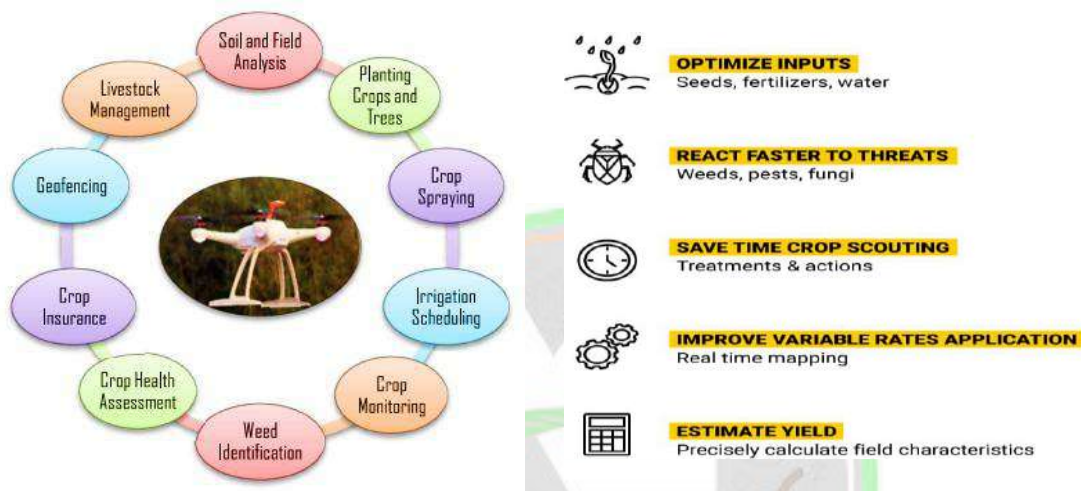


Fig.1: Application of drones in agriculture **Fig.2: Advantages of drones in agriculture**

3) Artificial Intelligence (AI)

AI enhances agricultural productivity by optimizing resource use and automating various farming processes.



Fig. 3: Applications of AI in Agriculture Role

of AI in Agriculture:

- Improves crop quality and accuracy



- Detects diseases, pests, and nutritional deficiencies in plants
- Identifies target weeds and determines precise herbicide application

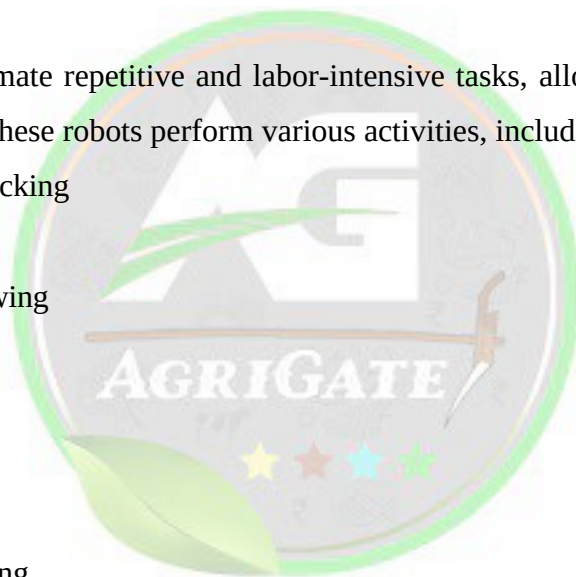
Examples of AI-based Agricultural Applications:

1. **Agri-Crop Mobile Application** - Assists in crop selection and management
2. **Multi-Informative Mobile Application** - Provides real-time agricultural updates
3. **Calculative Mobile Application** - Aids in farm budgeting and cost estimation
4. **Diagnostic Mobile Application** - Identifies plant diseases and soil deficiencies
5. **Agri-Academic Mobile Application** - Educates farmers on modern agricultural techniques
6. **Agri-Professional Mobile Application** - Connects farmers with agricultural experts

4) Robotics

Agricultural robots automate repetitive and labor-intensive tasks, allowing farmers to focus on optimizing production. These robots perform various activities, including:

- Harvesting and picking
- Weed control
- Autonomous mowing
- Pruning
- Seeding
- Spraying
- Thinning
- Sorting and packing



Conclusion

Digital agriculture has the potential to revolutionize farming and empower smallholder farmers by addressing challenges such as low yield and inefficient resource use. By leveraging digital tools, farmers can achieve greater productivity and sustainability. Collaboration among stakeholders, including governments, researchers, and technology providers, can further accelerate the adoption of digital farming solutions. As digital agriculture continues to evolve, it promises a prosperous and sustainable future for farmers worldwide.

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THE BIOLOGY AND MANAGEMENT OF UZIFLY: A KEY PEST OF MULBERRY SILKWORM

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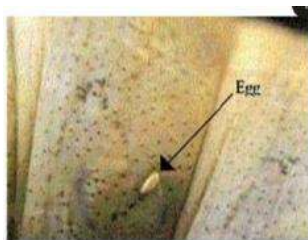
Introduction

India is unique in that it produces all four types of natural silks: *Bombyx mori* L., *Antheraea mylitta* L., *Samia cynthia ricini*, and *Antheraea assamensis*, which make Mulberry, Tasar, Eri, and Muga silks respectively. About 92% of India's entire raw silk production is made from mulberry silk. Insect and non-insect pests, as well as silkworm diseases, are among the many factors that affect the output of silk cocoons. The silkworm, *Bombyx mori* L. is known to be attacked by insects such as tachinid parasitoids, dermestid beetles, ants, earwigs, etc. The pests and parasites from groups other than insects are mite, nematode, wall lizards, rats, squirrels and birds which can also inflict considerable damage to silkworms. Uzi flies are a type of tachinid fly that infests and breeds on silkworms. There are at least four species of Uzi flies that infest different silkworms. These are the Japanese Uzi fly (*Crossocosmia sericariae*); the hime Uzi fly (*Ctenophorocera pavida*); the tasar Uzi fly, (*Blepharipa zebina*) and the Indian Uzi fly, (*Exorista sorbillans*). *Exorista sorbillans* (Louis), an endo-larval parasitoid of the silkworm *Bombyx mori* L., causes 10–20% reduction in cocoon yield in the traditional silk-producing states of south India. It also poses a continuous threat to the silk industry's survival by costing the industry between Rs. 100 and Rs. 200 crore annually.

Egg:

The egg of Uzifly is macrotype, small, oblong or elongated oval or bean shaped with pointed anterior end broadly rounded posterior end. The egg is creamy whitish and measures

0.50 to 0.59 mm in length and 0.20 to 0.31 mm width. The chorion is sculptured with reticulate pattern. The operculum is oval, subterminal, close to anterior end and has polygonal aeropyles.



Maggot:

The maggot is sub cylindrical, fusiform with wider posterior end and pointed anterior end. It is creamy whitish with yellowish tinge. It has 12 segments viz., one cephalic, three thoracic and eight abdominal segments. The posterior end is truncated.



Fig.2.8 : Uzi Maggot

Pupa:

Pupa is exarate, entirely covered in a transparent thin membrane which has a number of papilla like out growth providing room for the developing long setae. In male pupa the wing pads extend ventrally to the posterior margin of the opponent second abdominal segment and the legs extend beyond the anterior margin of the apparent fifth abdominal segment, whereas in the female wing pads and the legs stop short of the respective segment. The abdominal segmentation is clear and four segments are visible dorsally.



Adult:

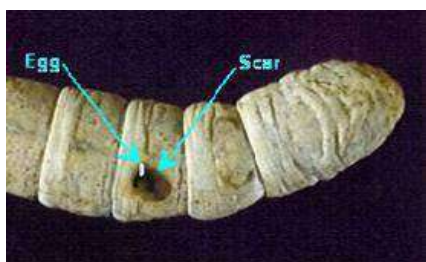
The adult flies were blackish grey and has four numbers of longitudinal lines on the thorax of the fly, as well as they, had long bristles on the lateral sides of the abdomen.



Time of Occurrence: It happens all year round, but it gets worse during the rainy season.

Damage Symptoms:

- During the first stage, the larvae's skin contains oval, creamy white eggs.
- The larval skin has a black scar on it.
- If silkworm larvae are assaulted in their early stages, they will die before they reach the spinning stage.
- Later on, a punctured cocoon is observed.



Life cycle: Fecundity: 350 – 400 eggs @ 1 or 2 eggs/silkworm

Incubation period: 2 – 3 days

Maggot stage: 5 – 7 days

Pupal period: 10 – 12 days

Total life cycle: 18 – 22 days

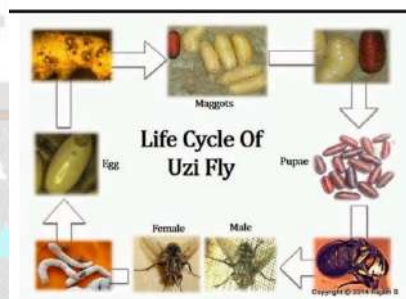
Management:

1. Exclusion method:

- Fix doors with automatic closing mechanism
- Provide ante-chamber at the entrance of the rearing house
- Install nylon net or wire mesh on all windows and doors

2. Uzi trap (tablet):

- It kills both the sexes of uzifly. Break down One tablet in one liter of water, and store the mixture in white trays outside and inside the raising house at the base of the windows from brushing to spinning.
- Place uzitrap inside the rearing house/mounting hall after spinning upto 20 days under close door condition to trap uziflies emerging inside.





3. Biological method:

- *Nesolynx thymus* is an ecto- pupal parasitoid of the uzi fly. About 40 to 60 parasitoids develop on each Uzi pupa.
- *Nesolynx thymus* is produced on house fly pupa. 50 ml of parasitized pupae in a nylon net pouch (Rs.50/pouch). About 10,000 NT adults emerge from each pouch.
- Release of *Nesolynx thymus* between 3rd to 5th day of Vth instar @ 2 pouches/100 dfls.
- After harvesting of cocoons, keep the same pouches near manure pit.



4. Cultural method:

- Separate the silkworm litter from mulberry twig. Do not throw silkworm litter in open area/litter pit, as it contains hundreds of uzifly pupa. Instead, place it in plastic bags and store it for 15 to 20 days to stop uziflies from emerging from the garbage. It can also be burned right away or buried in the ground.

Conclusion

In conclusion, the uzifly (*Exorista sorbillans*) stands as a significant pest of the mulberry silkworm (*Bombyx mori*), posing a major threat to sericulture worldwide. Its complex life cycle, characterized by parasitism of silkworms, leads to substantial economic losses in silk production. Understanding the biology of uzifly, including its reproductive behavior, host preferences, and developmental stages, is crucial for effective pest management strategies. Currently, various control measures are employed, such as biological control through natural enemies, chemical



treatments, and cultural practices. However, the over-reliance on chemical control has raised concerns regarding environmental impacts and the development of resistance. Therefore, integrated pest management (IPM) approaches, combining biological, chemical, and cultural methods, are recommended for sustainable control of uzifly infestations. Additionally, further research into the biology of uzifly and its interactions with silkworms will provide valuable insights into novel control tactics. Ultimately, a balanced approach, leveraging both traditional and innovative pest management strategies, will be essential in mitigating the threat of uzifly and ensuring the continued health of the mulberry silkworm industry.



TOMATO CARE MADE EASY: AVOIDING THE MOST COMMON DISEASES

Article ID: AG-VO5-I05-06**Abhinav Thakur***

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Abstract

Tomato (*Lycopersicon esculentum* Mill.) is one of the most important vegetable crop worldwide, cultivated on over five million hectares and yielding more than 186.8 million metric tons annually across the globe. Tomato is an important food and lucrative crop for many low-income farmers in the tropical countries. Despite its significant contribution to the global economy, tomato production faces major challenges due to various biotic and abiotic stresses. Various pathogens are responsible for causing diseases, including fungal (*Fusarium*, *Phytophthora*, *Botrytis*, and *Alternaria*), viral agents (*tomato spotted wilt virus*, *tomato mosaic virus* and *tomato yellow leaf curl virus*) and bacterial pathogens (*Xanthomonas vesicatoria*).

Keywords: Tomato diseases, Symptoms, Management.

Introduction

Tomato (*Lycopersicon esculentum*) belongs to family *Solanaceae* and ranks as the second most important vegetable crop after potato. It is suited for warm-season cultivation, requiring a climate with warm temperatures during the day and cooler conditions at night for optimal growth. Both warm and cool climates provide favorable conditions for the development of various foliar, stem, and soil-borne diseases which significantly affect the plant health. Different fungal diseases that affect tomato are - Early blight, Late blight, *Fusarium* wilt, *Verticillium* wilt, *Septoria* leaf spot, *Anthraco*se, *Damping-off*, *Gray mold*, *Powdery mildew*, *Root rot* and *White mold*; Bacterial diseases are - *Bacterial spot*, *Bacterial speck*, *Bacterial canker*, *Bacterial wilt*, *Tomato pith necrosis*, *Bacterial soft rot*, *Bacterial stem and Root rot*; Viral diseases are - *Tomato*

mosaic virus (ToMV), Tomato yellow leaf curl virus (TYLCV), Tomato spotted wilt virus (TSWV), Tomato leaf curl virus (ToLCV), Tomato ringspot virus (ToRSV), Tomato chlorosis virus (ToCV) and Potato virus Y (PVY). The important diseases of tomato are described below with the symptoms and management strategies (Panno et al., 2021); (Panthee, et al., 2024).

Foliar Diseases

Early Blight - caused by *Alternaria* species.

Initial symptoms include small brown spots on older leaves, which rapidly enlarge. These lesions often have a yellow halo and display dark, concentric rings that give them a distinctive "bullseye" appearance. As the disease progresses, similar symptoms can also appear on stems and fruits. On stems, early blight may cause collar rot, stem cankers, and sunken, elliptical brown lesions with lighter centers and characteristic concentric rings.



Management - Destroy the infected parts of the plant. Practicing crop rotation can significantly reduce the occurrence of the disease. For effective disease management, it is advisable to spray the crop with Difolatan at 0.2%, Dithane M-45 at 0.2%, or Bavistin at 0.1%.

Late blight- caused by fungus *Phytophthora infestans*

Symptoms first appear as irregular, water-soaked spots on the leaves, often with a pale halo, especially on the tender foliage within the plant canopy. As the disease progresses, these spots enlarge, causing the leaves to brown, wither, and die. The infection can also spread to stems and fruits at any stage of development. Affected tomatoes typically show mottled, sunken areas that are golden to dark brown, sometimes accompanied by white, fuzzy mold on the lesions.



Management - Use disease free seed and treat the seeds with Thiram @ 2–3 gm/kg before planting. Use Mancozeb (0.2%), Captafol (0.2%), Metalaxyl (0.2%), Copper Oxychloride (0.2%), or Tridemorph 80% EC at 1.5 ml per liter for disease control.

Septoria Leaf Spot- caused by *Septoria lycopersici*

The symptoms include light grey, round to oval necrotic lesions with black borders; on older leaves, the necrotic spots may have a chlorotic halo around them, and pycnidia may be seen in the middle of the lesions. As lesions



merge, chlorosis and defoliation occur. The disease spreads by overwintering in alternative hosts like *Solanum nigrum*, *S. carolinense* and *Datura stramonium* or in tomato plant debris.

Management - Removing and destroying the infected plant parts. Treating seeds with Thiram or Dithane M-45 at 2 gm/kg prevents seed-borne infections. In the field, spraying with Dithane Z-78 at a concentration of 0.2% provides effective disease control.

Tomato Wilt- caused by *Fusarium oxysporum* f. sp. *lycopersici*, Initial symptoms include yellowing of the lower leaves, browning of vascular bundle due to invasion of pathogen in the vascular bundle. This causes the plant to wilt, which results in collapse, and death of the plant at latter stages.



Management - Infected plants should uproot and destroyed. drenching should be done with 0.1% solution of Carbendazim, and seeds should be treated with Thiram @ 2.5 kg/ha. Practicing crop rotation with non-host crops like cereals can effectively lower the disease inoculum in the soil.

Damping off - caused by *Pythium*, *Rhizoctonia*, *Fusarium*, and *Phytophthora*.

Damping-off symptoms can occur both before and after the plant emerges from the soil. In pre-emergence damping-off, seeds fail to sprout and become soft, mushy, and brown, eventually decomposing due to infection. In post-emergence damping-off, seedlings emerge from the soil but die soon after. The affected areas, such as the roots, hypocotyls, and sometimes the crown, turn pale brown, become soft and waterlogged, and are thinner than healthy tissue. Infected stems may collapse, and the plants may be stunted due to root or collar rot.



Management - Soil drenching with copper oxychloride at 0.2% or Bordeaux mixture at 1%. To prevent pre-emergence damping off, treat seeds with *Trichoderma viride* @ 4 gm/kg or Thiram @ 3 gm/kg.

Buckeye Fruit and Root Rot - caused by *Phytophthora parasitica*

The infected leaves first show water-soaked, irregular-shaped lesions that quickly collapse and dry out. Initially, these lesions are dark green and water-soaked, eventually turning dry and brown. On stem as the lesions spread, they can fully girdle the stem, causing the pith tissue to brown and collapse. Fruit symptoms begin as



grayish-brown, water-soaked lesions that expand rapidly, forming brown concentric rings resembling a buckeye giving the disease its name. The brown discoloration can spread into the fruit's center, causing young green fruits to become mummified, while mature fruits rapidly rot due to invasion by secondary pathogens.

Management - To reduce the risk of infection, it's important to maintain proper drainage in the field. Stake the plants and remove foliage and fruits up to 15–30 cm above ground level. For effective management, spray Difolatan at 0.3% concentration, four times at 10-day intervals.

Bacterial Diseases

Bacterial canker of tomato- caused by *Clavibacter michiganensis* subsp. *Michiganensis*

Symptoms develop between fruit set and the onset of ripening. Leaves may roll upward, wilt, and dry, sometimes affecting parts or the entire plant. Yellowish to brown longitudinal streaks may appear on the stem, often accompanied by tumor-like structures. Infected berries may show small, dark lesions with bright halos, known as birds-eye spots. In advanced stages, extensive wilting and plant death occur.



Management - Hot water treatment of seeds at 50°C for 25 minutes is an effective method for disease control. Treat seeds with mercuric chloride at a 1:1000 ratio or soak in a Streptocycline solution (1g per 40 liters of water) for 30 minutes protects seedlings during the early stages of growth. Practicing crop rotation with non-host crops helps reduce disease occurrence.

Bacterial speck of tomato- caused by *Pseudomonas syringae* pv *tomato*
Infected plants initially exhibit hydropic, angular spots on the leaves, which may expand and merge into larger dark lesions surrounded by a chlorotic halo. On stems, elongated necrotic spots may develop, while fruits display small, rounded lesions, each encircled by a green halo, significantly reducing their marketability.



Management - Crop rotations such as cowpea-maize-cabbage, okra-cowpea-maize, maize-cowpea-maize, and finger millet-eggplant is effective. Treat seedlings with Streptocycline (1g/40 lt of water) for 30 minutes.



Bacterial wilt - caused by *Ralstonia solanacearum*

Pathogen first cause symptoms on young leaves to wilt during the day and recover at night. As it progresses, plants yellow, wilt completely, and collapse. Infected stems show brown streaks and ooze milky fluid, with bacterial streaming visible in water. Roots can rot and turn brown, and adventitious roots may form if the disease develops slowly.

Management - Use disease-free transplants, clean tools, and safe irrigation water. Crop rotation, good drainage, weed control, and raising soil pH help reduce disease. Drench soil with bleaching powder (4 kg/acre) and apply neem cake (100 kg/acre) further aid in control.

Viral Diseases

Tomato Spotted Wilt Virus

Tomato spotted wilt virus (TSWV) belongs to the genus *Orthotospovirus* and family *Bunyaviridae*. The initial symptoms on leaves can be mistaken for cold injury, as young leaves often show a purple coloration on the lower leaf lamina. As the disease progresses, chlorotic spots appear on the leaves, which later become necrotic. These necrotic areas gradually merge, giving the leaf a brown-violet appearance, commonly referred to as “leaf bronzing”. Necrosis can extend to the petioles, stems, and flowers, often accompanied by spots with chromatic alterations on the berries. Affected fruits exhibit light green spots, approximately 1 cm in diameter, which later become necrotic, sunken, and brownish in color. The spotted wilt virus is transmitted through thrips (*Thrips tabaci*, *Frankliniella schultzi* and *F. occidentalis*).



Management - Infected plants should be removed and destroyed. During weeding or earthing up, alternate or collateral hosts that may harbor the virus should also be removed to prevent the spread of the disease. Applying 2-3 foliar sprays of Dimethoate (0.05%) or Monocrotophos (0.05%) at 10-day intervals effectively controls the thrips population.

Tomato Yellow Leaf Curl Virus

Plant shows distorted leaves, side shoots, and reduced growth, resulting in a compact, bushy look with upright side and top shoots. Leaves typically shrink in size, turn yellow, and become deformed. In severe cases, young leaves lose most of their blade, leaving only the main vein. The leaflets often have yellowed, upward-curved edges, giving them a cupboard-like appearance. The spotted wilt virus is transmitted through thrips (*Thrips tabaci*, *Frankliniella schultzi* and *F. occidentalis*).



Management - Infected plants should be removed and destroyed, while weeding and earthing up will help eliminate alternate hosts. Whitefly can be controlled by applying Furadan at 1 kg a.i./ha during sowing and 1.5 kg a.i./ha after transplanting, along with spraying Dimethoate or Monocrotophos (0.05%) every 10 days. Cultural practices such as border cropping with maize, jowar, or bajra, planted 50–60 days before tomato transplanting, help block whitefly entry. Additionally, using polythene mulching with white, blue, grey, or black sheets can reduce disease spread, particularly when combined with Furadan application.

Conclusion

Tomato production is affected by various phytopathogenic fungi and bacteria, resulting in reduced yield and lower fruit quality. Successful control relies on accurately distinguishing between infectious and non-infectious diseases and identifying the specific microorganism responsible for the infectious diseases. Recognizing symptoms, understanding the distribution and spread of the disease, and knowing the methods for early detection of pathogens are essential for successful disease management.

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MICROBIAL BIOCONTROL AGENTS: AN ECO-FRIENDLY APPROACH TO CONTROL PLANT DISEASES

Article ID: AG-VO5-I05-07**Sweta***

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Abstract

Biological control of plant diseases is an environmentally sustainable strategy that involves the use of living organisms to suppress the activity of plant pathogens. This approach harnesses naturally occurring antagonists such as bacteria, fungi, and viruses to reduce disease incidence and severity in crops. These biocontrol agents work through a variety of mechanisms, including competition for nutrients and space, production of antimicrobial compounds, parasitism of pathogens, and induction of host plant resistance. The use of biological control not only minimizes dependence on synthetic fungicides and bactericides, but also reduces the risk of environmental contamination and the development of pathogen resistance. Advances in molecular biology, genomics, and microbial ecology have led to the discovery of novel biocontrol agents and improved formulations for field application. As part of Integrated Disease Management (IDM) systems, biological control plays a critical role in promoting plant health, enhancing crop productivity, and supporting sustainable agriculture.

Introduction

In crop production, fungi, oomycetes, insects, viruses, and bacteria are the most economically significant biotic stresses. Living-organism-caused plant diseases represent a serious threat to international security, accounting for 25% of losses. To prevent losses disease management is crucial. The most popular approach to managing them is still frequently chemical control. Nonetheless, the emergence of resistance in various pathogens and pests, the alleged harm to the natural ecosystem, the presence of toxic residues in the field, and consequent

environmental contamination have prompted the pursuit of safer substitutes, including the application of biological control agents (BCAs). Biological control is defined as the

Microbial biocontrol agents (MBCAs) offer an eco-friendly alternative to chemical pesticides for plant protection. These naturally occurring microorganisms, including bacteria, fungi, and viruses, can effectively manage pests and diseases without harming the environment or human health (Dey et al., 2021). MBCAs employ different mechanisms to control pathogens and they are highly specific, targeting particular pests while preserving beneficial organisms (Joshi et al., 2024). By integrating MBCAs into integrated pest management (IPM) strategies can reduce dependency on synthetic pesticides and prevent pesticide resistance.

Types of Biological control agents

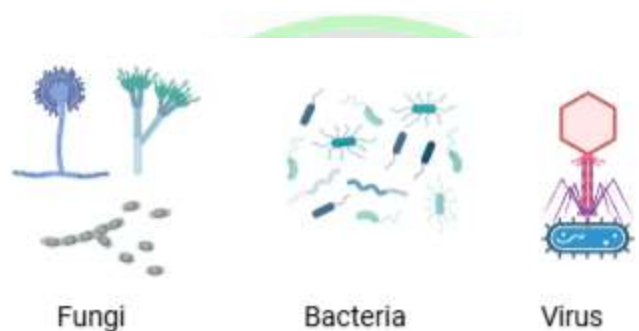


Fig 1. Different microbial biocontrol agents

Fungus-

Fungi are systematically and biologically assorted a large number of its parts to inhibit the growth of other pathogenic fungi which is harmful to plant development and advancement. The development of fungal strains as biocontrol agents of plant diseases has received a lot of attention. *Trichoderma* members are among the most often analyzed individuals. *Alternaria*, *Pythium*, *Aspergillus*, *Fusarium*, *Rhizoctonia*, *Phytophthora*, *Botrytis*, *Pyricularia*, and *Gaeumannomyces* are among the plant fungal pathogens that have been shown to be antagonistically affected by other fungi, such as *Penicillium*, *Gliocladium*, *Aspergillus*, and *Saccharomyces*. Beneficial root endophytes, such as *Glomus* spp. also be used as biocontrol agents.

Bacteria-

A wide variety of bacterial genera, including *Bacillus*, *Paenibacillus*, *Agrobacterium*, *Bradyrhizobium*, *Acinetobacter*, *Azospirillum*, *Azotobacter*, *Pseudomonas*, *Rhizobium*, *Alcaligenes*,

Arthrobacter, *Bacillus*, *Enterobacter*, *Erwinia*, *Pseudomonas*, *Rhizobium*, *Serratia* and *Streptomyces*, have been documented as biocontrol agents to control various diseases. Beneficial bacteria produce secondary metabolites and biofilms, including fengycin, bacillomycin, iturin, and surfactin, which lower the number of plant pathogens by forming plant-microbial interactions in the rhizosphere.

Virus

Several bacteriophages and mycoviruses are also found effective as BCAs against selective plant pathogen. Since mycoviruses have the ability to generate hypovirulence, or decreased virulence, in their hosts, there has been a lot of interest in characterizing viruses from phytopathogenic fungi due to their potential as biocontrol agents. *Cryphonectria parasitica* hypovirus 1 (CHV1) as a mycovirus that had entered the European populations of *Cryphonectria parasitica* and spread spontaneously, slowing the epidemic of chestnut blight.

Mechanisms of Biocontrol

1. Antibiosis- Antibiotic is microbial toxin that can kill pathogen at low concentration and this process of killing the pathogen by antibiotic is called antibiosis. Bacteria produce a variety of antibiotics, including non-volatile antibiotics such as polyketides, heterocyclic nitrogenous compounds (phenazine derivatives: pyocyanin, phenazine-1-carboxylic acid; PCA, PCN, and hydroxyphenazines), and volatile antibiotics such as hydrogen cyanide, aldehydes, alcohols, ketones, and sulfides. Various bacteriocins having antibacterial properties, including amylolysin, amylocyclin, amysin, subtilin, subtilisin A, subtilisin B, and thuricin, are produced by *Bacillus* species. The antifungal activity of *B. amyloliquefaciens* CPA-8 against *Monilinia* and *Botrytis* is facilitated by fengycin and volatile organic compounds (VOCs). *B. amyloliquefaciens* SP1 showed efficacy in biocontrol of *Fusarium oxysporum*, while *B. velezensis* was determined to be primarily responsible for pepper gray mold control by its hydrolase activity (protease, chitinase, cellulase, and glucanase). Numerous antimicrobial substances, including phenazines, phloroglucinols, dialkylresorcinols, pyoluteorin, and pyrrolnitrin, are found in *Pseudomonas*. These compounds have been shown to exhibit inhibitory activity against *Phytophthora cactorum* and *Fusarium graminearum* in strawberry plants.

Trichoderma produces different antibiotics, mycotoxins, and phytotoxins. *Trichoderma* secretes either antibiotics like viridin, gliotoxin, or peptaibols, or enzymes like glucanases, chitinases, and chitinases to inhibit the pathogen growth. Also, numerous secondary

metabolites, including trichodermin, gliotoxin, viridin, and peptide antibiotics, are also produced by this fungus. *Trichoderma* potentially prevent the growth of the *Fusarium* strain, *P. ultimum* and *Rhizoctonia solani*.

Competition- It is an indirect interaction that exclude infections by depletion of a food base or the physical occupation of a site. By reducing the availability of a certain chemical, the biocontrol agent can limit the growth of the pathogen and achieve biocontrol by nutritional competition. *Trichoderma* can compete with pathogens in plants for nutritional sources, viz. nitrogen, carbon, and iron and acts as a biocontrol agent against soil-borne plant pathogens. The rhizosphere competence of *Trichoderma* strains enables them to colonize the root surface and compete with other microorganisms for nutrients secreted by roots in rhizospheric soil. Siderophores are released by *Trichoderma* species and *Pseudomonas*, which sequester iron ions and prevent the pathogen from using them, thus helps in controlling pathogen. *Trichoderma*'s capacity to mobilize and adequately absorb soil nutrients gives it an advantage over many other soil microorganisms. This mechanism is used by *T. harzianum* against *Fusarium oxysporum* f. sp. *melonis*. Bacteria like *P. fluorescens* EPS62e and *P. pseudoalcaligenes* AVO110 inhibits *Erwinia amylovora* or *Rosellinia necatrix* infections by using this mechanism.

2. Hyperparasitism- This process involves the direct utilization of one organism as food by another. Fungi parasitic on other fungi are usually referred to as mycoparasites. Fungi have capacity to create enzymes that break down cell walls, which when combined with specific additional secondary metabolites, gives disastrous effects on the fungus that they infect. A variety of enzymes, including chitinase, protease, β -1,3-glucanases, and occasionally cellulases, are secreted by *Trichoderma* which leads to break down the fungal cell wall. Such a phenomenon is common in fungi but is rarely reported for bacteria. By producing extracellular enzymes as chitosanase, protease, glucanase, and cellulase, *Bacillus* species adhere to mycelial cell walls and deform hyphae.

3. Induction of host plant resistance- Induced systemic resistance is a form of active resistance that is dependent on the structural and biochemical barriers found in plants. Microbes induce structural changes include tyloses formation, cell wall thickening, and callose deposition in xylem channels or cork layers. Mycelial growth is inhibited and chitinase and β -1, 3-glucanase activities are increased when *Trichoderma* isolates are inoculated against *Sclerotium rolfsii*, *Colletotrichum gloeosporioides*, and *C. capsica* *in vitro*. Additionally, *Bacillus* species have

been shown to promote defense-related enzyme activity, including phenylalanine ammonia-lyase (PAL), polyphenol oxidase, and peroxidase, as well as root exudates and modifications, including amino acids and polysaccharides, to induce systemic resistance in plants against a variety of pathogens.

Conclusion

Microbial biocontrol agents offer an eco-friendly and sustainable alternative to chemical pesticides. They are highly specific to target pests, reducing harm to beneficial organisms and lowering the risk of resistance development. These agents also improve soil and plant health, are safe for humans and animals, and leave no harmful residues on crops. Additionally, they are cost-effective over time and integrate well with Integrated Pest Management (IPM) practices.

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EXPLORING THE HEALTH BENEFITS OF MAKHANA: A NUTRIENT RICH SUPERFOOD

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Introduction

India is a biodiverse country where a wide variety of plants are used as herbs for medicinal purposes. Immunoboosters like *Syzygium aromaticum* (Clove), *Mentha* (Pudhina), *Ocimum tenuiflorum* (Tulsi), *Cinnamomum verum* (Dalchini), and *Illicium verum* (Star Anise) are essential components of our kitchen and serve as flavoring and aromatic condiments. Because of their established therapeutic benefits, these herbs are therefore more useful for everyday tasks. Additionally, researchers are drawn to the active moiety of these herbs in order to learn more about their pharmacological properties. These herbs also don't have any negative side effects and are inexpensive. Comparably, the aquatic rhizomatous flowering plant *Euryale ferox* Salisb. (Nymphaeaceae) is a member of the *Euryale* genus. It is the only species of plant



endemic to sections of Korea, Japan, and India that is found throughout Eastern and Southern Asia. (7) One The plant is also known by several synonyms used throughout the world, including foxnut, foxnut, gorgonnut, semen Euryale's, Qian, and prickly water lily. (8) It is enjoyed as a dry fruit throughout India and is referred to as makhana. The specialty of the Bihar state's Mithila, Darbhanga, and Madhubani regions is traditionally Makhana. (10-11) Previous reports have mentioned the use of eryale ferox seeds in Ayurveda and Chinese remedies to treat renal disease, chronic diarrhea, excessive leucorrhoea, and liver malfunction. (12) .It was thought to somewhat boost cell-mediated immunity and humoral immunity when included in a regular diet.(13) The traditional uses of these foods, such as halua (semisolid preparation) and laddus (wheat flour balls), involve the common ingredient makana, or Euryale ferox. According to an old proverb, "The Euryale ferox seed is a grain dish, good for a baby and also for an old man—to prolong life," because of its capacity to support the kidney, strengthen the spleen, nourish the stomach, and reduce night-time enuresis. Makhana is therefore a nutraceutical supplement for a diet that is well- balanced.

Makhana (*Euryale ferox* Salisb.) is an aquatic crop belonging to the family of Nymphaeace. It is commonly known as gorgon nut or fox nut. Its seeds are also known as Black diamond. It is grown in stagnant perennial water bodies like ponds, land depressions, swamps and ditches (Liu et al., 2018). From the past few years makhana is also being cultivated in field system. In this system, makhana cultivation is carried out in agricultural fields at a water depth of one to two foot. India is the only country where makhana is cultivated as crop, mainly in the state of north Bihar and some parts of Assam and Manipur. In Northern part of Bihar, the major Makhana cultivating districts include Madhubani, Darbhanga, Katihar and Purnia (Nath et al., 2018). Makhana, or Fox Nuts or Lotus Seeds, is a fascinating and nutritious snack deeply rooted in Indian cuisine.

Its low-calorie nature makes it an ideal guilt-free snack, while its gluten-free and low-fat attributes cater to diverse dietary preferences. Makhana is considered as a native of South-East Asia and China, but distributed to almost every part of The world. However, its commercial cultivation is Limited to North Bihar, Manipur, parts of West Bengal And Madhya Pradesh. The total area under Makhana Cultivation in India is about 15,000 ha (ICAR National Research Centre for Makhana Research, Darbhanga). The production of Makhana seeds is about 1,20,000, Which after being processed yield 40,000MT of Makhana pop. The estimated value of Makhana

Production at farmer's end is Rs.250 crores and it Generates the revenue of Rs.550 crores at trader's level. (Anonymous, 2010).

Nutritional Benefits of Makhana:

Makhana is an aquatic cash crop with high carbohydrate, protein, and low-fat content. **Makhana** can be used to make a range of nutraceutical and functional foods. Makhana contributes high market value, 1.72% consumption out of 3.46% production remainit loose as wastage. The makhana production of about 80% is a market surplus (Khadatkar et al., 2020). e raw makhana contains 76.9% carbohydrates, 12.8% moisture, 9.7% protein, 0.9% phosphorus, 0.5% minerals, 0.1% fat, 0.02% calcium and 0.0014% iron. In popped makhana 84.9% carbohydrate, 4% moisture, 9.5% protein, and 0.5% fat. The seeds of the plant, commonly known as fox nuts or gorgon nuts, are harvested, **Processed**, and consumed as a snack or ingredient in various dishes. Makhana is rich in protein, fiber, antioxidants, and **Essential** minerals such as magnesium, potassium, and phosphorus. It is also low in calories and fat, making it a healthy food Choice. It has 12.8% in it. It is composed of 76.9% water, 9.7% protein, 0.1% fat, 0.02% calcium, 0.9% phosphorus, and 0.5% and 0.004% other minerals. Makhana (*Euryale ferox*), also known as gorgon nut, contains good mineral profile, starch, protein lacking gluten-forming properties and health-promoting bioactive compounds (Mridula et al., 2020). Semi-popped makhana (SPM) is a by-product obtained during popping of makhana seed and nutritional quality of this might be similar to popped makhana. Additionally, popping at high temperature causes the gelatinization of its starch and can be advantageously used to make gluten-free products.

Health Benefits of Makhana:

The most significant action of makhana is the antioxidant activity of foxnut connected to medical conditions like proteinuria inhibition or diabetic nephropathy. When evaluated with DPPH, TEAC, and CAT (Catalase) SOD (Superoxide Dismutase) activity, foxnut (*Euryale ferox* Salisb) extracts show enhanced rates of radical scavenging behaviour, decreasing power, and are a powerful antioxidant because it reduces lipid peroxidation. Additionally, it improves cell viability, guards against H₂O₂-driven apoptosis, and enhances the functionality of certain antioxidant enzymes. Foxnut is a considerable source of natural antioxidants. the ability to be employed as dietary supplements, functional foods, and medications for hyperlipidemia and diabetes. They contain the flavonoid kaempferol. According to Tehseen et al. (2000) and Rahul et al. (2002), flavonoids have anti-inflammatory properties and have an anti-free radical action.

The edible part of the seed is the starchy kernel, which cannot be separated easily from its hard shell. Therefore, the raw makhana seeds are generally processed (popping) to obtain popped makhana for edible use. The consumption of popped makhana has been increased worldwide in the past few years due to its health benefits, lightness, and crispiness (APEDA, 2017).

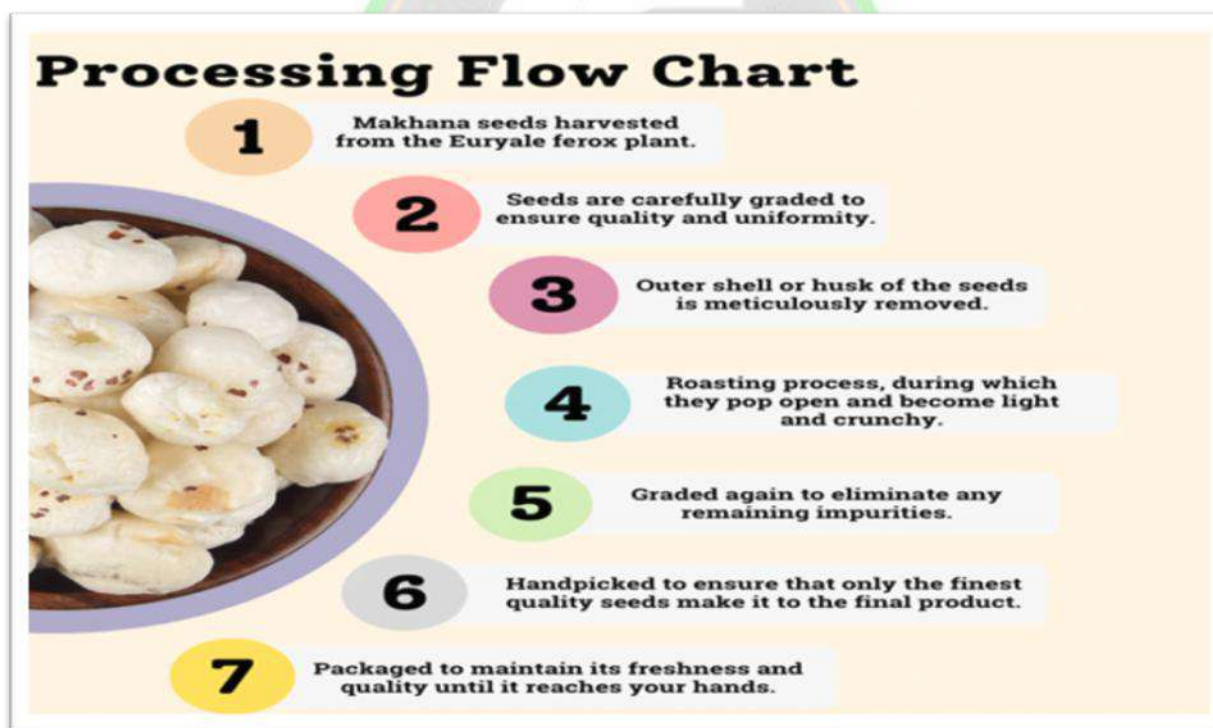


Production and Processing of Makhana:

Makhana Cultivation Conventionally, makhana was being grown exclusively in the ponds and perennial water bodies, particularly by the fishermen communities of north Bihar. (29) However, to meet its rapidly growing global demand and to materialize the income potential from makhana farming, productivity and the area under makhana cultivation both need to be increased. As the number of ponds and natural water bodies is believed to decline gradually, the introduction of makhana cultivation in field conditions, like rice, has recently been started to expand the area under makhana cultivation. The processing of *Euryale ferox* (commonly known as makhana) involves several labor-intensive and specialized steps, often carried out using traditional methods.

The process includes drying, size grading, preheating, tempering, roasting, and popping. Here's a detailed breakdown of the steps: 1. Drying: After harvesting, the seeds are dried to facilitate the removal of the seed coat. 2. Size Grading: The seeds are sorted using different sized sieves to separate them into various grades based on size. 3. Preheating and Tempering: The graded seeds are heated in a pan for about six minutes at temperatures ranging from 230°C to 335°C while continuously stirring. 4. Resting: The seeds are left in open baskets for 40 to 50 hours, which helps in loosening the seed coat from the kernel. 5. Roasting: After resting, the seeds are roasted again at approximately 230°C to 335°C until they start to crack. 6. Popping:

Once crackin occurs seeds are placed on a hard surface and struck with a hammer. This breaks the seed coat and allows the seed kernel to expand and pop out. 7. Polishing: The popped seed kernels are polished by rubbing them against a bamboo basket to remove any remaining seed coat and prevent moisture absorption. 8. Final Grading: The seeds are graded based on their size and color before being packed and sent to the markets From the past few years makhana is also being cultivated in field system. In this system, makhana cultivation is carried out in agricultural fields at a water depth of one to two foot. India is the only country where makhana is cultivated as crop, mainly in the state of Bihar and some parts of Assam and Manipur. Bihar accounts for more than 85 per cent of the makhana produced in the country. Northern part of Bihar, constituting districts of Madhubani, Darbhanga, Katihar and Purnia is highly suitable for makhana cultivation. Cultivation of makhana is highly cumbersome, labour intensive and involves human drudgery. Fishermen community belonging to the weaker sections of the society is mainly involved in makhana sector.



Culinary uses of Makahana:

Makhana flour, arrowroot flour wheat flour, besan raw and Chopped cabbage were used to prepare different products like makhana Barfi, makhana kalakand, and makhana pakora. Different procedures Are given below:Makhana Barfi was prepared from raw makhana powder

(300 g), Sugar (200 g) milk (1.5 liters) pure ghee (5 g), elaichi powder (2 g), Arrowroot powder (2 g) and then mixed them properly for ready to Boil. The boiling temperature was 130-140°C for 30 minutes to thick Consistency then cut into small pieces after cooling. Makhana Kalakand was prepared from raw makhana powder (300 g), sugar (100 g), channa (600 g), milk (1.0 lit), pure ghee (5 g) and elaichi powder (2 gm). The boiling temperature was 130-140°C for 30 minutes to a thick consistency and then cut into small pieces after Cooling of the resultant mass. Makhna Chapatti The recipe of the makhana chapatti was raw Makhana powder (250 g) bread wheat (Atta: 250 g) and pure ghee or Oil (10 ml). The dough was made with the help of water. Chapatti was Then fried in a nonstick pan at about 150°C (for roasting). Makhna Pokora was made from makhana raw powder (250 g), Pure besan (150 g) and soybean oil (250 g). Pakora was fried and scan On a spoon at about 150°C.

Economic importance of Makhana:

Cultivation of makhana has immense Potential for enhancing the economic status of The Mallah (Fishermen) community who are Particularly engaged in cultivation. Makhana Cultivation may be promoted by the state Government along with NRC, Darbhanga and Training cum demonstration programme on Practices should be imparted for efficient Cultivation. Makhana cultivated in pond System is totally an organic product. This Aspect of Makhana should be highlighted and Promoted among the developed countries of The world to fetch foreign exchange. Scientific Community can also help in boosting up the Marketing of makhana by highlight the Nutritional values and other benefits. In view of the economic importance of makhana (*Euryale ferox* Salisb.), its seed has been deservedly called as 'Black Diamond'. Given its rapidly rising global demand, the crop holds great Promise for eastern India, particularly Mithilanchal region of north Bihar.

Foxnut as a superfood:-

The seeds were marketed and utilised in stuffing. foxnut that has been sifted and grated is a common ingredient in prepared foods. it is frequently used to make a variety of milk-based foods, such as custard and kheer. foxnuts that have been roasted and fried and dusted with spices and oil are a common snack. the seeds are fried and then eaten as a snack or added to curries and other vegetable meals. (49-50) Foxnut powder is added to pua to make up for protein and mineral shortages . Creation of a wholesome and consistent baby food recipe to enhance children's cognitive and behavioural development. It has been discovered and used that popped foxnuts

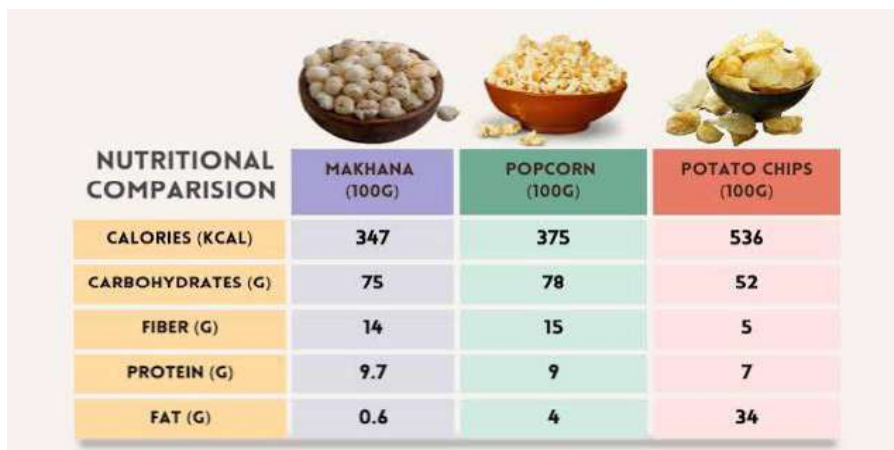
have been applied into the baked goods. The texture and consistency of the gluten-free bun or bread can be improved by adding popped and puffed foxnuts. Makhana flour is used to make a variety of sweets, including makha-na kalakand and makhana barfi. Another way to make makhana chapatti and makhana cabbage is to combine makhana flour with another type of edible flour. Products made from makhana have a low sugar content, decent expansion, and appealing colour that appeals to health-conscious consumers.

Conclusion:

It is a highly nutritious food, abundant in Nutritional and bioactive compounds such as carbohydrates, protein, fiber, vitamins, Minerals, and polyphenols. It is considered a functional food owing to its various Health benefits such as antidiabetic, antihyperlipidemic, antifatigue, hepatoprotective, cardioprotective, antimelanogenic, etc. *E. ferox* has immense potential in both Food and non-food industries. Regardless of being recognized as a superfood packed With nutritional as well as medicinal properties, it is still neglected, and there has not Been much attention given to its cultivation. Therefore, in this review, the potential of *E. ferox* as a superfood has been explored to enhance its utilization in the development Of different foods and make it available outside its growing area.

Future aspects:

Makhana Rich in protein, fiber and minerals like calcium and iron, Makhana is an excellent snack option for those looking to manage weight. It's high antioxidant content help protect against oxidative stress and inflammation, potentially reducing the risk of chronic disease and diabetes. The future of makhana looks promising, with opportunities for sustainable production, global market expansion, and culinary innovation. Makhana is a high-valued aquatic



NUTRITIONAL COMPARISON	MAKHANA (100G)	POPCORN (100G)	POTATO CHIPS (100G)
CALORIES (KCAL)	347	375	536
CARBOHYDRATES (G)	75	78	52
FIBER (G)	14	15	5
PROTEIN (G)	9.7	9	7
FAT (G)	0.6	4	34

crop due to its rich source of carbohydrates and protein. The operations involved in its cultivation as well as processing is very drudgerious and painful activity. Hence, it is cultivated in eastern region of the country in about 13,000 to 15,000 ha area. Due to its tradition cultivation practice, the mechanization level is also very low and generally done manually by a particular community i.e. Mallah.

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ROLE OF BIOFERTILIZER IN AQUACULTURE

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Introduction

Biofertilizers, also known as live fertilizers, consist of specific groups of microorganisms that play a vital role in mobilizing nutrients. They convert nutrients from their complex organic or inorganic forms into simpler, available forms for plants and animals. These are ready-to-use live formulations of beneficial microorganisms that, when applied to seeds, roots, or soil and water, enhance nutrient availability through their biological activity. This process helps build beneficial microflora, thereby improving both soil and water health. Biofertilizers add essential nutrients from the environment into the soil or aquatic environment, reducing the need for inorganic fertilizers and pesticides. As a result, they help minimize aquatic environmental pollution and lower the risk of disease spread among fish and humans. There are certain biofertilizers used in aquaculture, such as *Azolla*, *Rhizobium*, *Azotobacter*, *Azospirillum*, and various species of blue-green algae (including the genera *Nostoc*, *Anabaena*, *Tolypothrix*, and *Aulosira*) have been used in aquaculture for a long time to promote survival, growth of beneficial microorganisms, plankton, etc., and achieve higher economic income.

How useful bio-fertilizer

Biofertilizers are safe to use and help lower the reliance on inorganic fertilizers, minimizing disturbances to the aquatic environment and reducing the risk of food spoilage and negative impacts on human health. They are more cost-effective than chemical fertilizers, eco-friendly, and have no harmful side effects on fish growth performance during application. Using

biofertilizers as a fertilizer source can increase output income. Biofertilizers can enhance crop yields by 10-40% and are capable of fixing 40–50 kg of nitrogen per hectare. They also improve soil and water quality parameters such as pH, salinity, carbon-to-nitrogen (C: N) ratio, and water hardness. Additionally, biofertilizers do not contain any inorganic chemicals that could harm living organisms in the soil or aquatic species like finfishes or shellfishes.

Classification of biofertilizers

Aquaculture farmers are increasingly using high doses of chemical fertilizers, which deteriorate soil structure, damage soil properties, reduce water retention capacity, and negatively affect fish health and flesh quality. Biofertilizers provide the only sustainable solution to overcome this situation and ensure the continuation of aquaculture practices across generations. Based on the microorganism biofertilizers divided into three types:

1. Algal biofertilizers
2. Bacterial biofertilizers
3. Fungal biofertilizers

Algal biofertilizers

Azolla

Azolla is a heterosporous fern that belongs to the family *Azollaceae*. It is a free-floating fern that fixes atmospheric nitrogen through a symbiotic relationship with the cyanobacterium *Anabaena azollae*, which resides in its dorsal leaf cavities and also releases hydrogen (H₂) during nitrogen fixation. Azolla has the capacity to fix nitrogen, ranging from 1.0 to 2,6 kg/ha in one day. Its ability to rapidly multiply, fast decomposition rate, and quick nutrient release. Azolla survives in a wide pH fluctuation of 3.5-10. Better growth of azolla occurs within an optimum pH range of 4.5-7 and salinity up to 10ppt.

Cyanobacteria

Blue-green algae, known as cyanobacteria, are capable of both free-living life and symbiotic relationships. These microbes play an important role in aquaculture by increasing primary productivity and mobilising nitrogen. In order to fix atmospheric nitrogen and make it available to aquatic plants and microorganisms, important cyanobacterial genera like *Anabaena*, *Nostoc*, *Colothrix*, *Aulosira*, and *Scytonema* are employed as biofertilizers. This process promotes the growth of phytoplankton and zooplankton, which serve as natural food sources for fish and shrimp. Additionally, Cyanobacteria also contribute to stabilizing pond ecosystems,

accelerating nutrient cycling, and reducing the need for chemical fertilizers. Additionally, their activity supports better fish health, increases survival rates, and enhances overall productivity in aquaculture systems. Some cyanobacteria, such as *Anabaena azollae* in association with *Azolla*, are particularly valuable for their rapid nitrogen-fixing ability and their contribution to sustainable aquaculture practices.

Bacterial biofertilizers

Bacterial biofertilizers are widely used in aquaculture to improve water quality, enhance nutrient availability, and promote the growth and health of aquatic organisms. Beneficial bacteria such as *Rhizobium*, *Azotobacter*, *Azospirillum*, and phosphate-solubilizing bacteria help fix atmospheric nitrogen, solubilize phosphorus, and mobilize other essential nutrients, making them easily available for phytoplankton and aquatic plants. This leads to the natural enrichment of the aquatic environment, supporting the food chain for fish and shrimp without the need for chemical fertilizers. Bacterial biofertilizers also improve soil structure at the pond bottom, accelerate the decomposition of organic waste, enhance microbial biodiversity, and stabilize the pond ecosystem. Their use results in better growth rates, higher survival rates, improved fish health, and increased production, making aquaculture practices more sustainable and economically viable.

Azotobacter

Azotobacter is a free-living, gram-negative, motile, and mesophilic bacterium that fixes nitrogen at an average @ 20kg/ha/year. The genus *Azotobacter* belongs to the subclass of the *proteobacteria* and there are some species for nitrogen fixing seven species: *A. chroococcum*, *A. vinelandii*, *A. beijerinckii*, *A. paspali*, *A. armeniacus*, *A. nigricans* and *A. salinestri*. Dutch microbiologist and botanist Martinus Beijerinck first discovered *A. Chroococcum* found in natural pH (7-7.5) and alkaline pH (8.5-9) in soil.

Rhizobium

Rhizobium is a bacterium found in leguminous plants' roots that fix nitrogen in the soil @ 50-100 kg/ha. *Rhizobium* belongs to the family Rhizobiaceae, is gram-negative, motile, non-sporulating, and fixes atmospheric nitrogen symbiotically. The seven genera of *Rhizobium* are highly specific to legume root plants.

Fungal biofertilizer

Many fungi are present in aquatic systems, and different genera exhibit distinct

characteristics such as bioremediation, nutrient cycling, enhancement of soil fertility, improvement of water quality, disease control, and promotion of growth and survival rates in aquatic organisms. Certain fungi, especially mycorrhizal fungi and phosphate-solubilizing fungi such as *Aspergillus niger* and *Penicillium* species, have the ability to release organic acids and enzymes that convert insoluble phosphorus into soluble forms, which can be absorbed by aquatic plants and phytoplankton, thereby promoting primary productivity.

Some fungal strains are also effective in bioremediation by decomposing organic waste, thereby reducing toxic compounds such as ammonia (NH₃), nitrite, and hydrogen sulphide in pond water. For instance, species like *Trichoderma harzianum* and *Aspergillus* spp. degrade organic matter, stabilize pond sediments, and help maintain good water quality. Additionally, *Trichoderma* species exhibit strong **antagonistic properties** against pathogenic bacteria and fungi by producing antibiotics, enzymes, and secondary metabolites that inhibit the growth of harmful microorganisms. Furthermore, mycorrhizal fungi such as *Glomus* spp. enhance nutrient uptake in plants, which is particularly beneficial in aquaponics systems where plant and aquatic animal cultivation are integrated.

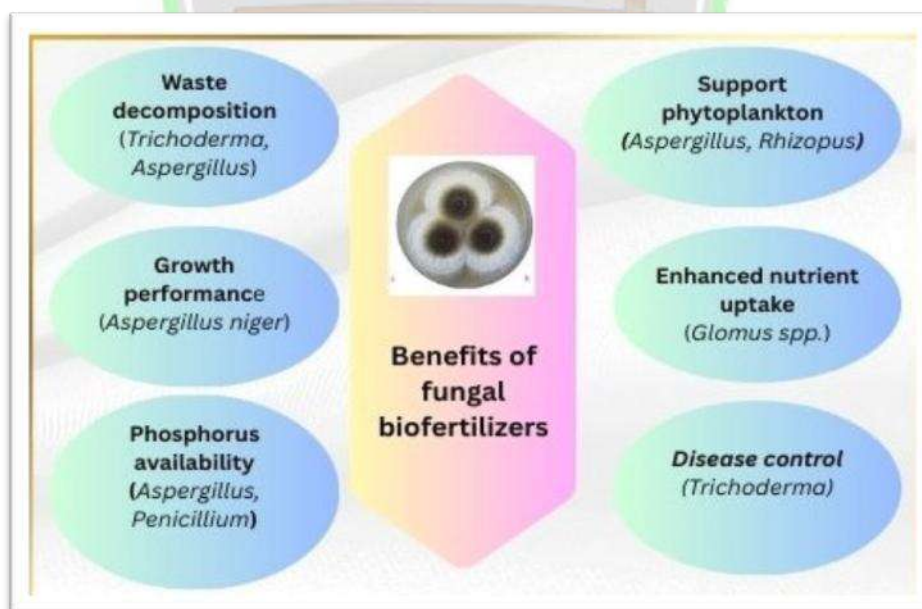
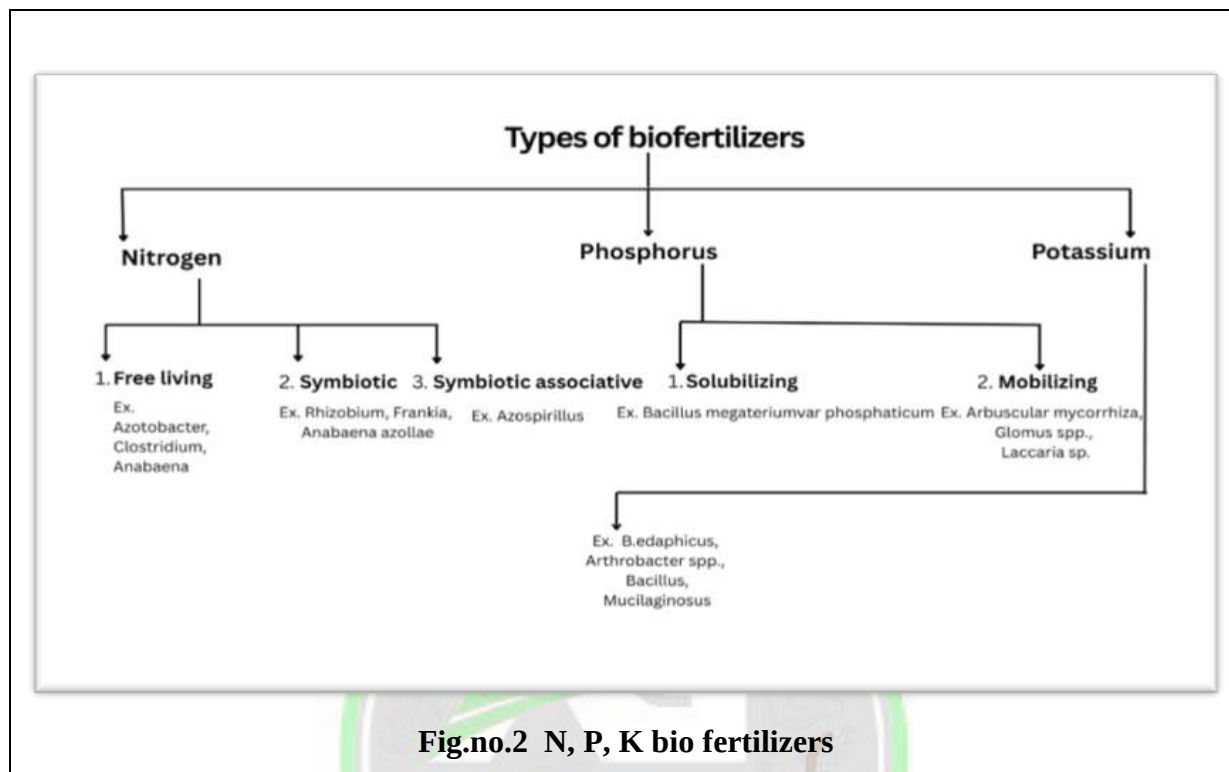


Fig. No.1 Fungal Biofertilizers

Types of biofertilizers:



1. Nitrogen biofertilizers

Fish farmers are facing a major challenge in managing nitrogen compounds such as ammonia (NH_3), nitrite (NO_2^-), and nitrate (NO_3^-) within aquaculture systems. These nitrogen compounds primarily coming from fish feed, fish excreta, and the decomposition of organic matter. Their accumulation can lead to eutrophication, ammonia toxicity, and overall deterioration of water quality, all of which negatively impact growth and survival or aquaculture production. The use of nitrogen-fixing biofertilizers in aquaculture offers a sustainable and eco-friendly solution to this problem. These biofertilizers enhance natural microbial processes that convert atmospheric nitrogen into bioavailable forms, which can be utilized by aquatic plants. This not only improves nutrient cycling but also helps maintain better water quality in aquaculture systems.

2. Phosphorus biofertilizers

Phosphorus is a limiting nutrient in freshwater ecosystems, yet it is an essential macronutrient for the growth of aquatic plants, including phytoplankton, which support primary

productivity. In aquaculture systems, phosphorus is introduced primarily through feed and the application of inorganic and organic fertilisers. However, much of this phosphorus becomes locked in insoluble forms within the sediment, making it unavailable for uptake by aquatic plants. This leads to inefficient nutrient utilisation, environmental accumulation, and increases the risk of eutrophication. Phosphorus biofertilizers, which consist of beneficial bacteria and fungi, play a crucial role in converting these insoluble forms of inorganic phosphorus into soluble forms that can be readily utilised by aquatic plants, thereby enhancing nutrient cycling and water quality.

3. Potassium biofertilizers

Potassium is a major macronutrient that plays important physiological roles in aquatic plants and photosynthesis, including osmoregulation, enzymatic activity. It also plays an indirect role in maintaining ionic balance and supporting the health of aquatic organisms. However, in aquaculture systems, much of the potassium is present in insoluble forms, making it unavailable for uptake by aquatic plants and algae. Potassium biofertilizers comprising specific microorganisms such as bacteria (*Bacillus mucilaginosus*, *Frateruria aurantia*) and certain fungi have the ability to convert insoluble inorganic potassium into bioavailable forms that can be readily utilised by aquatic plants.

Advantages of using Bio fertilizer in aquaculture:

- Help in increased bio-availability of nutrients, especially the organic nitrogen and phosphate.
- Bio fertilizer can replace 25-30% chemical fertilizers and reduce input costs.
- Increase in pond productivity by slow-release nutrients and improve the phytoplankton growth as well as fish production.
- Minimizes physico-chemical water parameter fluctuation, especially pH and alkalinity.
- Helping in decomposing plant materials, thereby improving C: N ratio of soil, improving soil texture and structure, and increasing water holding capacity.
- Some bio-fertilizer microorganisms such as bacteria, fungi and algae, secrete antibiotic-like substances that reduce disease.
- Increase soil organic matter and maintain a good soil texture.
- It's cheaper than chemical fertilizer.



- Bio-fertilizer use to increase fish production as well as economic performance.

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TRUE POTATO SEED (TPS): AN APPROACH TO POTATO CULTIVATION IN INDIA

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Introduction

Potato is the most important vegetable crop in the world in terms of human consumption. Potato is a staple food crop in India and many other countries. In many remote areas in India where seed potatoes are not available, potato yield is much lower (4-11 tonnes/hectare) than the national average yield of 18.2 tonnes/hectare. There may be several reasons for the low yield of potatoes in these areas. Such as:- 1) Non-availability of quality seed potatoes of high yielding varieties at affordable prices 2) Inadequate availability of critical inputs like fertilizers, pesticides etc. 3) Poor management practices followed by potato growers and unfavorable agro-climate have led to the spread of serious potato diseases such as blight, bacterial wilt, viruses potato tuber moth, white grub, which adversely affect the quality seed potatoes in the region. Hence in most of the northeastern states seed potato tubers are regularly procured from remote places in the north 4) There are inadequate facilities for storage of seed potatoes.

The concept of exploring the potential of TPS to raise commercial potato crop from TPS in India was first realized in the early 1950s by Dr. S. Ramanujam, the first Director of the ICAR-Central Potato Research Institute, Shimla. The TPS is a botanical seed as a result of sexual reproduction, which



True Potato Seed

develop as a small seed inside the fruit known as a berry. Depending upon genotype and environment, a single potato plant may have 50-100 berries. A berry contains 200-250 seeds and 1 g TPS may contain 1500-2000 seeds. In India, TPS is produced through bi-parental crosses. Hybrid TPS population perform better than open-pollinated families as regards yield (Luthra *et.al.* 2009).

Potential for TPS technology as an alternative

In view of the above problems and constraints faced by potato growers, TPS (true potato seed) can be used as an alternative technology to increase productivity and reduce the cost of potato. TPS has several advantages over traditional seed tubers:

- TPS is a low-cost planting material and is of great use to small and subsistence farmers, providing them a viable alternative to overcome the disadvantages of clonal propagated tuber seeds production. TPS has several advantages over conventional seed tubers: Only 100-120 grams of TPS is required for one hectare, while about 3 tonnes of seed tubers are required for planting in the same area. The seed tubers thus replaced can be saved for table purpose.
- Problems related to tuber-borne diseases, especially viruses, are substantially reduced as TPS carries fewer pathogens. Except for Potato Virus T (PVT) and Potato Spindle Tuber Viroid (PSTVD), no other potato disease is transmitted through TPS.
- The cost of seedling tubers obtained from TPS is about one-tenth of the cost of quality seed tubers required for planting one hectare (about Rs 50,000-80,000).
- TPS is convenient and inexpensive to store from one planting season to the next and can even be stored for several years under ambient conditions by maintaining seed moisture content between 3-5% during storage.
- Easy transportation, as only 100 grams of TPS is required instead of about 3 tonnes of seed tubers for planting in one hectare area.
- TPS provides an opportunity to fit potatoes into different cropping systems as tuber seeds of the right physiological age may not be available to farmers as per their requirement. The TPS will also help expand potato cultivation in agricultural areas that were previously unable to produce potatoes due to a lack of good quality seed tubers or in hot humid tropical regions where seed tubers could not be produced or stored.

- The multiplication of healthy/quality planting material through TPS is much faster than the traditional process of certified seed production. The use of TPS can eliminate the production of foundation and basic seeds required in the formal tuber seed production system. Pathogens are unable to affect the TPS crop unlike the clonally propagated crop due to inherent resistance (multilineal effect). However, one or two need based sprays of insecticides can be given for control of late blight and aphids. Therefore, TPS is not only cost effective but also environmental friendly.

TPS can be a viable solution to mitigate the problem of non-availability of quality potato seeds in remote areas. Moreover, breeder seed production cannot be taken up in the mid-hill and lowland regions as the area under potato cultivation is higher here than in the high hill regions. Moreover, most of the potato farmers in this region are small and marginal. Therefore, TPS can be a suitable technology for them due to its low cost of cultivation. Some states like Meghalaya, Manipur, Nagaland and Arunachal Pradesh grow potatoes in two seasons. Therefore, the sprout tubers produced in a season can be easily stored in diffused light at ambient conditions and used for potato production in the next crop season. Thus the need for expensive cold stores can be eliminated by the use of TPS in these states. Crop can be produced by transplanting or by planting sprouted tubers produced in the previous season and storing them in cold stores. 0.5-1.0 ton of sprouted tubers are required for planting one hectare, And less space will be required for storage in the cold storage, whereas about 3 tonnes of seed potatoes will be required for planting in the same area.

TPS production and use

Production of TPS: True potato seeds (TPS) are formed in small fruits that develop on potato plants after self- or cross-pollination and these fruits are known as berries. Depending on the genotype and environment, a potato plant can have about 50-100 berries. One berry contains 150-200 seeds and 1 gram of TPS can contain



Production of TPS

about 1500-2000 seeds. These TPS are used for potato production. TPS can be produced in both hilly (summer) and plain (winter) areas. In hilly areas (long days), potatoes flower naturally,

whereas in plain areas (short days), day length has to be artificially increased to 16 hours per day to induce flowering.

Potato production from TPS

TPS can be used by raising seedlings in nursery and transplanting them in the field in the same season or by planting seedling tubers (G₀ generation) obtained from nursery to grow commercial potato crop in the next season. The yield obtained from TPS can be maintained as seed for next 3-4 years by following strict control regime against aphids and late blight.



Preparation of Nursery Bed

Crop from seedling transplanting:

This is suitable for areas where production of healthy seed tuber and its storage is expensive and difficult. In this method the seedlings are raised in nursery beds, where enough FYM is applied. Seedlings of 30 days age are transplanted (at 3-4 leaf stage) in field at 60 cm × 10 cm spacing. About 150 g TPS and 75 m² nursery bed area is required to produce sufficient seedlings for transplanting in one hectare area. This method is quite suitable for raising commercial crop in the states of Assam, eastern UP, Bihar, West Bengal, Madhya Pradesh and Gujarat, but is unsuitable for Punjab, Haryana and western UP where the temperatures at planting are high and winters are also severe, resulting in stunted growth of the seedlings crop and consequent low yields. The transplanted crop requires assured irrigation facilities and thus is not suitable under rainfed condition.

Crop from seedling tubers:

This system requires two seasons. In the first season seedling tubers are produced, which in the second season are planted to grow the main crop. The seedling tubers are produced by transplanting seedlings in nursery beds at 25 × 4 cm (for plains) and 10 × 10 cm (for hills) spacing or by direct seeding of TPS (2 seeds per hole) at the same spacing. About 40 g TPS and 300 m² nursery bed area is required to produce enough tubers for planting one hectare area in the next season. The seedling tubers when used as seed give as good or even better yields than the seed of standard varieties.

Out of the two approaches of TPS, the approach consisting of raising the crop from seedling tubers is better and simulates the traditional potato cultivation. This approach has also scope in the plateau areas where *kharif* and *rabi* crops are taken. The seedling tubers produced in *rabi* season could be used as seed in *kharif* season, thus reducing the dependence on the seed produced in the northern states of the country.

Recommended TPS populations for cultivation:

TPS populations, viz., HPS- I/13, TPS C-3 and 92-PT-27 have been recommended for commercial potato cultivation in the country. 92-PT-27 has been found most suitable for potato cultivation in the northeastern region (Gaur 1999).



Production from 92-PT-27 TPS

Demerit of TPS technology

TPS crops take 15-20 days longer to mature than seed tubers. Crops grown from TPS are less uniform in plant type and maturity, tubers produced from them may show greater variation in size, colour, etc. than tubers produced from clones or varieties. Potato plants are sensitive to environmental stress and damage due to insects/pests and hence labour requirements are high during the initial stages of growth and establishment especially in transplanted crop. Though TPS technology is labour-intensive, it requires low initial capital to grow potato crop. This combination is suitable for small and marginal farmers who have a lot of family labourers and less capital.

Conclusions

TPS technology is scientifically sound, technically feasible, economically viable and environmentally friendly. TPS also provides an opportunity to small farmers to produce high quality planting material and ensures higher yield with less productive material compared to tuber seed with unknown health status. Although there are certain bottlenecks that hinder the adoption of TPS among farmers, they can be overcome by introgressing desired traits from different genetic resources and further improving the parental lines by adjusting the planting dates as well as agricultural practices according to the local conditions. The success of adoption of TPS in a state like Tripura can be used as a model for TPS technology in areas where transportation of potato tubers is a problem. Policy decision and full support of the State Government along with wide expansion of this technology to farmer groups in different villages



can pave the way for successful adoption of TPS technology. The same strategy, if adopted in other seed deficient states, will help in adoption of TPS technology and its use by farmers to produce healthy planting material and increase potato productivity at the state and national level.

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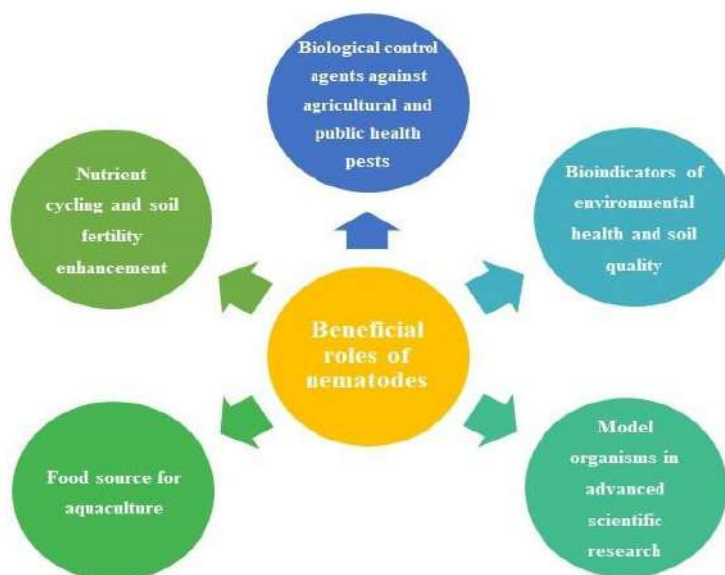
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THE BENEFICIAL ROLES OF NEMATODES IN NATURAL AND AGRICULTURAL ECOSYSTEMS

Article ID: AG-VO5-I05-11**Berliner J^{1*}, Manimaran B², Sellaperumal, C.² and Venkatesan, M.³****1^{*}ICAR-IARI, Regional Station, Wellington, Tamil Nadu 643231, India****2ICAR-IISR, Kozhikode, Kerala 673012, India****3ICAR-CTRI, Research Station, Jellugumilli, Andhra Pradesh 533466, India*****Corresponding Author Email ID: berliner.j@gmail.com**

Introduction

The existence of every organism on earth serves a purpose—this holds true for both beneficial and pathogenic forms. The classification of organisms into “useful” or “harmful” categories is largely anthropocentric, reflecting human interests and values. Nematodes, microscopic thread-like organisms, are widely recognized for their parasitic nature affecting humans, livestock, and crops. However, it is important to note that parasitic nematodes account for less than 1% of the total known nematode biodiversity. The vast majority of nematode species play beneficial roles in ecosystems, particularly in the following areas:



1. Nematodes as Biological Control Agents Against Insect Pests

a. Entomopathogenic Nematodes (EPNs)

Entomopathogenic nematodes (EPNs) are free-living soil nematodes known for their ability to rapidly kill insect pests within 24–48 hours. They accomplish this with the help of symbiotic bacteria such as *Xenorhabdus* spp. and *Photorhabdus* spp., which they release inside the host. The most prominent EPN genera are *Steinernema*, *Heterorhabditis*, and *Neosteinernema*, belonging to the families Steinernematidae and Heterorhabditidae. These nematodes actively seek out insect larvae, particularly those entering the soil for pupation, and invade their bodies through natural openings such as the mouth, anus, and spiracles. Once inside the gut, they penetrate into the haemocoel by breaching the soft tissues of the alimentary canal. Notably, species of *Heterorhabditis* possess tooth-like structures that enable direct penetration through the insect's integument. Inside the haemocoel, the nematodes release their bacterial symbionts, which multiply rapidly and cause death through septicemia.

This dual action—biological and biochemical—confounds the insect's immune response and hastens mortality. Furthermore, antimicrobial peptides produced by the bacteria prevent secondary infections from other microbes, preserving the cadaver for nematode reproduction. EPNs can be mass-reared and applied in the field without the need for protective equipment, making them an environmentally safe and user-friendly biocontrol option. They are widely used against insect orders such as Lepidoptera, Diptera, and Coleoptera (Grewal et al., 2005).

b. Entomo-parasitic Nematode

Entomo-parasitic nematodes are nematodes that parasitize insects and have been explored as biological control agents in various pest management programs. One significant application is in the biological control of mosquitoes, a growing concern in public health. Certain nematodes, particularly mermithid species like *Romanomermis culicivorax*, target aquatic mosquito larvae. The infective juveniles penetrate the larval cuticle, develop inside the host, and eventually kill it before emerging to continue their life cycle. Their host specificity and non-toxic mode of action make them suitable alternatives to chemical larvicides, especially in ecologically sensitive areas. Another notable example is the control of the Sirex woodwasp (*Sirex noctilio*), a major pest in pine plantations, using the entomo-parasitic nematode *Beddingia siricidicola*. This classical biological control method involves inoculating trees and plantations with the nematode. Successful implementation depends on selecting virulent nematode strains, optimizing culturing

and storage techniques (including cryopreservation), and conducting field monitoring to assess effectiveness. These examples demonstrate the potential of entomo-parasitic nematodes in sustainable pest management strategies.

2. Nematodes as Bioindicators of Environmental Health and Soil Quality

Free-living nematodes are highly sensitive to changes in soil structure, chemistry, and biological activity. Their population dynamics, species diversity, and trophic structure can serve as reliable indicators of soil health and environmental disturbances such as pollution, erosion, and land degradation. The presence or absence of specific nematode functional groups—bacterivores, fungivores, omnivores, and predators—can help assess ecosystem balance and guide sustainable land management practices. For example, *Plectus murrayi* thrives in undisturbed, healthy soils but is sensitive to pollution, making it an indicator of soil health. Similarly, *Rhabditis* spp. are found in soils contaminated with heavy metals, serving as a bioindicator for pollution. *Cephalobus* species, which correlate with specific microbial communities critical for soil fertility, are also important bioindicators of soil quality. Additionally, quantitative indices such as the Enrichment Index (EI) and Maturity Index (MI), derived from the composition of nematode communities, provide valuable insights into nutrient availability and ecosystem stability. High EI values reflect nutrient enrichment and microbial activity, while higher MI values indicate a more stable and less disturbed soil environment.

3. Nematodes as Model Organisms in Advanced Scientific Research

The nematode *Caenorhabditis elegans* is one of the most extensively studied model organisms in biology. It has contributed significantly to our understanding of genetics, neurobiology, developmental biology, and aging. Its transparent body, short life cycle, and well-mapped genome make it ideal for laboratory research. *C. elegans* was the first animal to have its entire genome sequenced, consisting of approximately 100 million base pairs (approximately 97 Mb) and around 20,000 genes. Discoveries made using *C. elegans* have led to several Nobel Prizes and opened up new avenues in molecular biology, including RNA interference (RNAi) and programmed cell death (apoptosis). In addition to *C. elegans*, other nematodes such as *Pristionchus pacificus*, *Panagrellus redivivus*, and *Meloidogyne incognita* are also used as model systems. *Pristionchus pacificus* serves as a comparative model in evolutionary developmental biology due to its divergent developmental pathways, while *Panagrellus redivivus* is commonly used in toxicological studies and educational settings. *Meloidogyne incognita*, a plant-parasitic

nematode, is widely studied for understanding host-pathogen interactions and plant resistance mechanisms. A comprehensive source of information about *C. elegans* biology and its research applications is available at WormBook (www.wormbook.org), an open-access, peer-reviewed collection of articles written by experts in the field.

4. Nematodes in Nutrient Cycling and Soil Fertility Enhancement

Nematodes are integral components of the soil ecosystem, playing a vital role in nutrient cycling and the enhancement of soil fertility. By feeding on soil microbes such as bacteria, fungi, protozoa, and even other nematodes, they help regulate microbial populations and stimulate microbial turnover. This grazing activity accelerates the decomposition process and mineralization of essential nutrients, particularly nitrogen, making them more readily available for plant uptake. As nematodes consume microorganisms, they release excess nitrogen in the form of ammonium, thereby linking microbial biomass to plant nutrition. Their activity also promotes the release of other nutrients like phosphorus and sulfur, while their movement through soil improves aeration and aids microbial dispersal. Additionally, nematodes contribute to the stability and complexity of the soil food web, supporting ecological balance and suppressing soil-borne pathogens through competition and predation. These functions are critical in both natural and agricultural systems, enhancing long-term soil health, boosting crop productivity, and reducing reliance on chemical fertilizers. As such, nematodes are not only indicators of soil quality but also active agents in sustaining soil fertility and ecosystem resilience.

5. Nematodes as a Food Source for Aquaculture

Nematodes serve as a valuable food source for various small-scale and laboratory-reared animals due to their high protein content, ease of cultivation, and suitability for feeding young or small aquatic organisms. Among the commonly used species is the microworm (*Panagrellus redivivus*), which is a staple in aquaculture for feeding fish fry. These nematodes are small enough to be consumed by larvae and are cultured on simple substrates like fermented oatmeal or yeast media. Their active movement makes them attractive to young fish, enhancing feeding efficiency. Another species of interest is the vinegar eel (*Turbatrix aceti*), a free-living nematode often found in unpasteurized vinegar (Berliner et al., 2024). Though not widely used in commercial settings, vinegar eels are occasionally used as live feed for small aquarium fish. They are appreciated for their tolerance to acidic environments, long shelf life, and minimal

maintenance requirements. These examples illustrate the broader potential of nematodes as an alternative protein source in aquaculture.

Conclusion

Nematodes, though often associated with parasitism and crop damage, play a far more diverse and beneficial role in ecosystems. Less than 1% of nematode species are parasitic; the vast majority are free-living and contribute significantly to soil health, pest management, nutrient cycling, and scientific advancement. As biological control agents, nematodes such as *Steinernema* spp., *Heterorhabditis* spp., *R. culicivora*., and *B. siricidicola* species provide eco-friendly alternatives to chemical pesticides by targeting insect pests in both agriculture and public health settings.

Beyond pest control, free-living nematodes act as sensitive bioindicators of soil quality and environmental health. Their community composition and trophic structure help detect disturbances like pollution, erosion, or nutrient imbalances. Indices such as the Enrichment Index (EI) and Maturity Index (MI), derived from nematode assemblages, offer powerful tools for assessing nutrient availability and ecosystem stability, guiding sustainable land management practices.

In addition, nematodes contribute to critical ecosystem services such as nutrient mineralization, microbial regulation, and soil aeration. Species like *Caenorhabditis elegans* and *Pristionchus pacificus* serve as important model organisms in biological research, while others like *Panagrellus redivivus* are used in aquaculture as live feed. Recognizing and promoting the multifaceted roles of nematodes is essential for advancing sustainable agriculture, ecological resilience, and innovation in life sciences.

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HARNESSING VERMICOMPOSTING FOR EFFECTIVE ORGANIC WASTE REDUCTION

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Introduction

Vermicomposting is a biological process of composting organic wastes through domesticated earthworms under controlled conditions. It is the compost which is prepared by earthworms. It is a mixture of worm casting (faecal excretions) organic materials including humus, live earthworms, their cocoons and other micro-organisms. It is the process of breaking down the organic portion of solid waste non-thermophilically and stabilizing it using a combination of earthworms and bacteria in a regulated environment (Deka *et al.*, 2011; Pramanik, 2010). Vermicomposting is the process of turning organic waste into nutrient-rich compost using earthworms, (Benitez *et al.* 2000). It has become a popular and environmentally acceptable way to handle solid waste. Vermicomposting is an effective method for sustainable waste management and the promotion of agricultural sustainability. Earthworms have tremendous ability to compost all biodegradable materials. Waste subjected to earthworm consumption decompose 2 to 5 times faster than in conventional composting. During composting the wastes are deodorized, pathogenic micro-organisms are destroyed and 40 to 60 % volume reduction in organic wastes take place. It is estimated that the earthworms feed about 4 to 5 time their own weight of material daily. Earthworms bears both male and female reproductive organs. However, two worms are needed for successful copulation. The self-fertilization does not occur generally in the earthworms. Fertilization take place in the egg case or cocoon. It improves soil

health and soil fertility, also improves soil structure, enhance plant growth, maintain soil PH, harvest bio-fertilizers and generate bio-conversion product.

Types of earthworms:

Earthworms are one of the first multicellular invertebrates, belonging to the phylum Annelida and class Oligochaeta. It may be found in forest, field and garden in all over the world ranging from a few centimetres to over a meter long. There are nearly 3000 species of earthworms reported in the world. Among them 509 species are available in India. They breathe through their skin and have a moist slimy covering that makes it easy for them to move through soil. Among all some species are suitable for vermicomposting i.e. *Eisenia foetida*, *Eudrilus eugenia*, *Lampito mauritii*, *Pherionyx excavatus*, *Octochaetoma serrata*, etc.

These earthworms are mainly divided into three groups:

- a) **Epigeic (surface feeder)** – Epigeic earthworm present at or near the soil surface and it decomposes cattle dung, herbal waste, rice straw, soybean straw, garden waste, and tea residues. *Eisenia foetida* is one of earthworm's species which is frequently employed for the purpose vermicomposting process.
- b) **Endogeic (Geophagus/humus feeder)** – These earthworms feeds deeper beneath the soil surface, ingesting large quantity of organically rich soil. These are not suitable for vermicomposting.
- c) **Anecic**- These are found in deeper soil layer. This species are also suitable for vermicomposting

Vermiculture:

It is the process of rearing and breeding of earthworms in controlled condition. It is estimated that 1800 worms which is an ideal population for one sq. meter can feed on 80 tonnes of humus per year. Faecal matter or excretions of earthworms is known as vermin cast. Vermi wash is a liquid fertilizer collected after the passage of water through a column of worm activation, which is useful for foliar spray on different crops. It may be diluted with water before use. It can also be diluted with 10% urine of cow. The average nutrient content of vermicompost is about 0.5 to 0.9- 0.1 to 0.2- 0.67 % N, P, K respectively.

Vermiwash:

Vermiwash is a liquid manure which is a transparent pale yellow coloured fluid collected after the passage of water through a column of worm action or it a collection of excretory

products and mucus secretions of earthworm along with nutrients from the soil organic molecules. It is very useful as a foliar spray to enhance the plant growth and yield and to check development of diseases.

Characteristics of earthworms suitable for vermicomposting:

- The worms should have feeding preference and adaptability to wide range of organic materials.
- It should be fast Growth rate, maturity from young one to adult stage.
- It should be efficient converter of plant/animal biomass to body proteins.
- It should have high consumption, digestion and assimilation rates.
- The worms should produce large number of cocoons.
- The worms should feed near the surface of organic matter.
- It should be tolerant to diseases, wide adaptability to environmental factors and have least inactivity period.

Benefits of vermicompost:

- Vermicompost improves physical, chemical and biological properties of soil in the long run on repeated application.
- The multifarious effects of vermicompost influence the growth of plants and increase agricultural yields. It gives essential nutrients, strengthens the structure of the soil, increases its ability to hold water, and increases the availability of nutrients for plants.
- It improves nutrient cycling and retention, it enriches the soil with organic matter, increasing soil fertility, nitrogen, phosphorus, potassium, calcium, magnesium, and trace elements are among the macro- and micronutrient levels that increase in the soil and are essential for plant growth. When added to clay soil, loosens the soil and provides the passage for the entry of air.
- The mucus associated with it being hygroscopic, absorbs water and prevents water logging and improves water holding capacity.
- In the vermicompost, some of the secretions of worms and the associated microbes act as growth promoter along with other nutrients. It has disease-suppressive properties that reduce the incidence and severity of specific plant diseases.

- Earthworm can minimize the pollution hazards caused by organic waste by enhancing waste degradation. it is beneficial for the environment because it keeps organic waste out of landfills and lowers greenhouse gas emissions. Methane production, a powerful greenhouse gas, is reduced by recycling organic waste using vermicomposting (Sharma *et. al.*, 2019).

Parameters to be considered for vermicomposting:

- Temperature is main factor in vermicomposting as its affects the metabolism, rate of reproduction and the growth of earthworms. Decrease in temperature below 10°C increases the stress on the earthworms and freezing temperatures can kill the earthworms. Increase in the temperatures can also reduce the activity of the earthworms leading to the reduced reproduction rate finally affecting the activity of vermicomposting.
- Optimum temperature range – 15°C to 30°C
- Moisture content: Earthworms contain nearly 75% to 90% of water in their bodies and they breathe from their skin and if they dry up earthworms cannot breathe and will eventually die.

Application of vermicompost:

For field crops vermicompost should be applied @ 5t/ha. In orchards the dose vermicomposting depends on the age of the tree. It can be used @ 500 g in small fruit plants and 3 – 4 kg/tree whereas for vegetable crops @ 3 kg/10 m² area.

Conclusion

In conclusion, vermicomposting stands out as a remarkably eco-friendly approach to solid waste management. Through the symbiotic relationship between earthworms and organic waste, this process not only effectively reduces the volume of waste but also transforms it into nutrient-rich compost, which can enhance soil fertility and promote sustainable agriculture. As we confront the challenges of waste management and environmental sustainability. Embracing vermicomposting represents a tangible step towards building a more resilient, regenerative, and harmonious relationship between human activities and the natural world.

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REVOLUTIONIZING FISH PROCESSING WASTE: ECO-FRIENDLY TECHNOLOGIES FOR SUSTAINABLE UTILIZATION

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Introduction

Seafoods were valued for their nutritional benefits, such as superior protein quality, vital vitamins and minerals, and health-promoting unsaturated fats. Their highly perishable nature required effective processing methods to ensure their freshness, quality, and safety. Consumers of the time preferred lightly processed seafood that preserved its natural qualities and nutritional value (Getahun et al., 2025). Reusing seafood bio-waste is vital for bio-economies, turning low-value waste into valuable products. With rising global seafood consumption, waste generation has surged about 25% of 175 million tons in 2017 became waste. Crustaceans yield only 40% edible meat, leaving 60% as waste, totaling 7–9 million tons in 2020. This waste is rich in nutrients, including proteins, oils, and chitin, which can be converted into bioactive compounds and biodegradable polymers. Effective waste management supports environmental sustainability and circular economy goals (Zhao et al., 2022).

Utilization of Fish Waste and Byproducts

Various terms such as “by-product,” “co-product,” “fish waste,” “fish offal,” “fish visceral mass,” and “fish discards” are commonly used to refer to the inedible portions generated during seafood processing. By-products include all remaining material, whether edible or inedible part left after the primary products have been processed. For finfish, typical by-products consist of trimmings, skins, heads, frames (bones with some flesh), internal organs (viscera), and blood. By-products from seafood processing are utilized in the production of food, fish meal, fish oil, hydrolysates (food and animal grade), pet food, nutraceuticals, cosmetics, leather, fuel,

fertilisers, and therapeutants (Kumar et al., 2018).

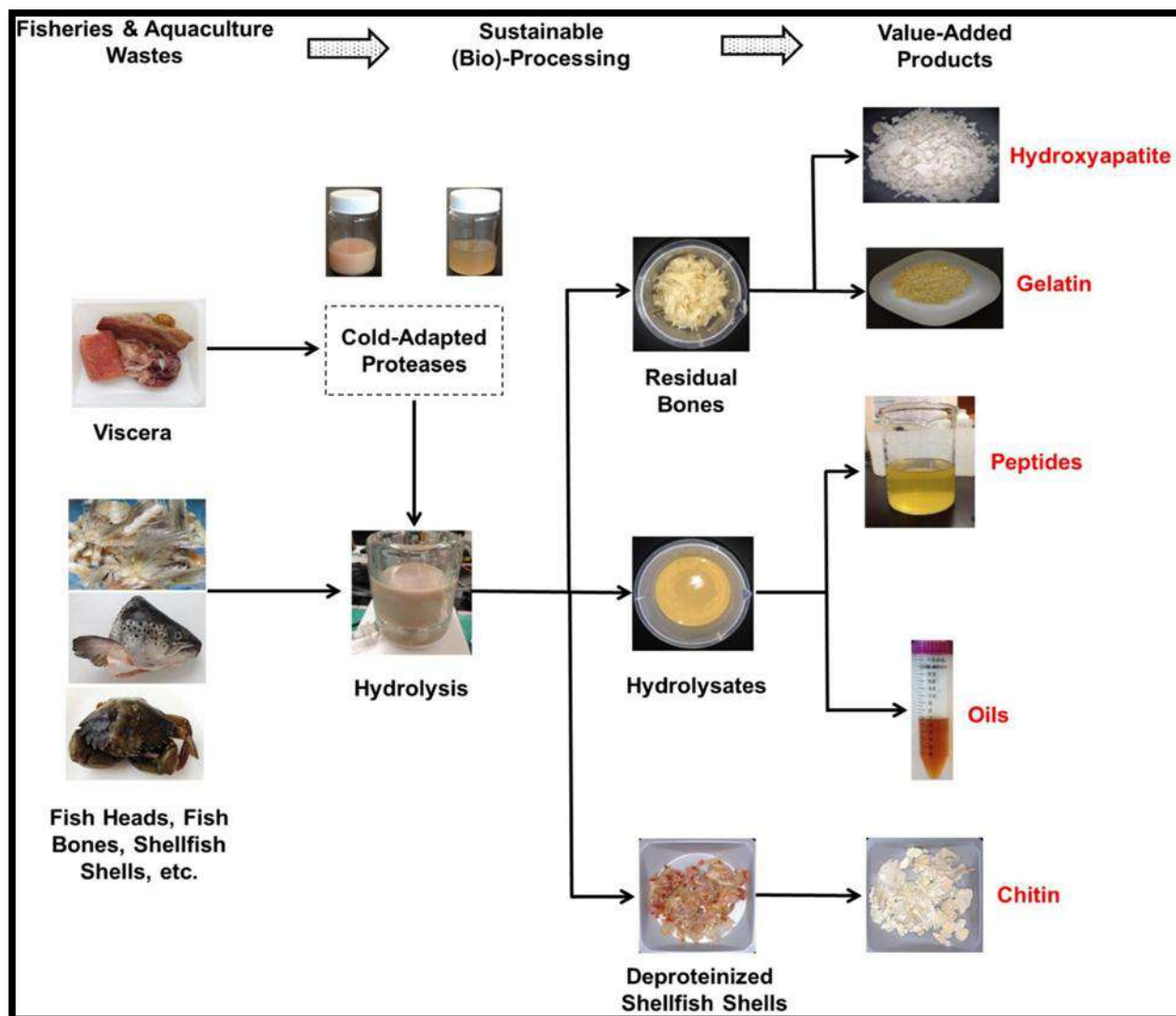


Figure 1: Utilization of Fish Waste and Byproducts

Fish meal and Fish oil

Fish oil and fish meal are important components of aquaculture feed, traditionally derived from pelagic fish. However, growing demand and limited availability have placed significant strain on marine ecosystems. To enhance sustainability, the industry has turned to using fish processing by-products such as heads, bones, guts, and blood for producing fish oil and fish meal, which are rich in proteins and omega-3 fatty acids like EPA and DHA. In a typical processing method, 400–500 tonnes of by-products are collected each day, cooked at temperatures between 90–95°C, and then separated using centrifugation. Fish oil is obtained from the liquid portion, while the remaining solids are dried at 160–180°C to create fish meal.

This approach helps to reduce waste and supports the nutritional requirements of farmed fish (Ido & Kaneta, 2020).

Fish protein hydrolysate

Fish protein hydrolysate (FPH) is created by breaking down fish proteins into smaller peptides through either enzymatic or chemical methods, which influence its nutritional and functional characteristics. These smaller peptides are often more effective than whole proteins or individual amino acids. The outcome of the hydrolysis process depends on several factors, including the type of enzyme, temperature, processing conditions, and the source material such as fish meat, skin, bones, or minced fish (Kristinsson & Rasco, 2000).

Fish silage

Fish silage is a highly nutritious liquid protein source created by breaking down whole fish or fish parts using natural enzymes in an acidic environment, which helps speed up the process and prevents spoilage. It can be made from spoiled fish, low-value species, processing waste, and industrial leftovers. The proteins in fish silage can be further converted into free amino acids, making it a valuable feed ingredient. The process typically involves chopping the fish, adding 3% formic acid, and storing the mixture for 48 days at a pH below 4. Another method uses fermentation, where the fish is mixed with molasses and inoculated with *Lactobacillus plantarum*, then incubated and heat-treated. Fish silage can also be mixed with wheat bran and dried to lower moisture content, improving shelf life and nutrition. Besides being a protein source, fish silage can also yield useful bioactive substances like oil, peptone, and pepsin, especially from cod and salmon, with specific storage and processing methods enhancing their extraction (Ghaly et al., 2013).

Collagen and gelatin

Fish skin waste serves as an excellent source of collagen and gelatin, which are commonly used in the food, cosmetic, and medical industries. Gelatin is a partially broken-down form of collagen, and both are rich in non-polar amino acids such as glycine, alanine, valine, and proline. Compared to bovine sources, fish-derived collagen and gelatin are safer as they pose no risk of bovine spongiform encephalopathy (BSE). Additionally, gelatin extracted from fish skin through enzymatic methods shows superior antioxidant and blood pressure-lowering effects due to its distinct glycine-proline-alanine sequence (Ghaly et al., 2013).

Chitin and chitosan

Chitin is an environmentally friendly natural polymer composed of N-acetyl-D-glucosamine units and is primarily found in the shells of marine organisms such as shrimp, crabs, and lobsters, making crustacean waste a rich and accessible source. It typically exists along with proteins, calcium carbonate, and various pigments. Due to its biodegradable and biocompatible nature, chitin has a wide range of uses across industries such as agriculture, medicine, cosmetics, water treatment, and food technology. Chitosan, a derivative of chitin formed through partial removal of acetyl groups, is a non-toxic co-polymer widely utilized for similar purposes. In a specific process, shrimp shells were gathered, boiled, peeled, dried, and stored for extraction. These shells underwent deproteinization using a 2% sodium hydroxide solution at 90°C for two hours, followed by centrifugation and drying (Khanafari et al., 2008).

Bioactive peptides

Bioactive peptides are naturally produced in living organisms and have potential uses in nutraceuticals and pharmaceuticals. They can be isolated using acid, alkali, enzymatic hydrolysis, fermentation, or solvent extraction. These methods break down proteins into small peptides (2–20 amino acids). The yield depends on protein structure, enzymes, and conditions like temperature and time. Fish are a rich source, and peptides from their parts like skin and bones show various health benefits such as antimicrobial, antioxidant, and antihypertensive effects (Behera et al., 2022).

Conclusion

The sustainable utilization of fish processing waste represents a transformative shift in the seafood industry, aligning with global goals for environmental conservation and circular bio-economy development. By converting nutrient-rich by-products into valuable resources such as fish meal, fish oil, protein hydrolysates, silage, collagen, gelatin, chitin, chitosan, and bioactive peptides, the industry not only minimizes waste but also adds economic and ecological value. These eco-friendly technologies reduce pressure on marine ecosystems, lower production costs, and create novel opportunities across sectors like aquaculture, agriculture, pharmaceuticals, and cosmetics. Embracing these innovations is essential for ensuring the long-term sustainability and resilience of the seafood supply chain.

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AVOCADO (*PERSEA AMERICANA*) – GLOBAL DEMAND AND SUSTAINABLE FARMING

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Introduction

The global demand for avocados is increasing due to their health benefits and rising awareness of healthy eating. Avocados are a good source of vitamins, minerals, and healthy fats, and are known to improve digestion, vision, and heart health.

Factors driving demand

Healthy lifestyle: People are increasingly focusing on healthy eating and looking for healthier alternatives.

Nutritional awareness: People are becoming more aware of the nutritional value of avocados.

Growing middle class: The growing middle class is driving demand for healthy food products.

Rising import demand: Demand for avocados is increasing from countries where production is declining.

Avocado-based products: The popularity of avocado-based snacks and convenience foods like guacamole is driving demand.

Avocado-based products

Avocado oil: Avocado oil is used in cosmetics and personal care products due to its moisturizing and antioxidant properties.

Avocado-based snacks: Avocado-based chips, crackers, and popcorn are becoming more popular

Avocado-based convenience foods: Avocado-based convenience meals like guacamole cups and dips are becoming more popular.



Sustainable avocado farming involves using practices that protect the environment and natural resources while also being economically viable. These practices include water conservation, cover-cropping, and no-till farming.

Sustainable avocado farming practices

Water conservation: Use efficient irrigation methods, like drip irrigation, to reduce water waste

Cover-cropping: Use plants to cover the soil and enrich it with nutrients.

No-till farming: Avoid tilling the soil, which can damage it.

Eco-friendly pest and disease control: Use methods that don't harm the environment.

Precision agriculture: Use data to make decisions about farming, which can improve productivity.

Rainwater harvesting: Collect rainwater to use for irrigation.

Sanitation: Provide workers with sanitation services and education.

Blood tests: Test workers who apply fertilizer to ensure they aren't contaminating the environment.

Biodiversity protection: Avoid hunting and grazing cattle to protect the natural ecosystem.

Sustainable avocado farming can benefit farmers, the environment, and consumers.

HUMIC ACID FOR SUSTAINABLE CROP PRODUCTION

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Introduction

Soil health is a crucial factor for realizing higher yield of crops. Excessive application of chemical fertilizers may affect soil health and sustainable productivity. So addition of organic manures, which can supplement nutrient requirement of crops to some extent, release nutrient in a gradual and controlled way and enhance production of crops without much impact on the environment. Humus is the end product of the microbial decay of organic matter. Humus is relatively stable and fairly resistant to further rapid breakdown and it is a food source for soil micro flora.

Modern day soils have been over-cropped, abused and depleted of organic matter and certain essential elements. Any changes in natural conditions will result in changes in humus content of the soil. These changes are irrigation, drainage, deforestation and intensive cultivation of crops which lead to rapid and marked changes in humus balance of the soil. In recent years soil scientists, agronomists and farmers realised the importance of maintaining the humus content of soils as an aid to increase the crop productivity mainly to increase or at least to maintain the status of humic materials in the soil.

Humic substances for sustainable crop production

Humic substances (HS) are the largest constituent of soil organic matter (~60%), known to contain complex and heterogeneous mixture of polydispersed materials formed by biochemical and chemical reactions during the decay and transformation of plant and microbial

remains (a process called humification). The importance of humic substances (HS) in agriculture in general and soil health in particular has been acknowledged for over 150 years. They cannot be decomposed readily because of their intimate interactions with soil mineral phases and are chemically too complex to be used by microorganisms.

As far as soil is concerned, one of the most striking characteristics of HS is their ability to interact with metal ions, oxides, hydroxides, mineral and organic compounds including toxic pollutants to form water-soluble and water-insoluble complexes through the formation of these complexes, HS can dissolve, mobilize and transport metals and organics in soils and water or accumulate in soil horizons. Accumulation of such complexes can contribute to a reduction of toxicity in soil.

Humic substances have positive effects on plant physiology by improving soil structure and fertility and by influencing nutrient uptake and root architecture and they have been shown to contain auxin and an “auxin-like” activity but the biochemical and molecular mechanisms underlying these events are only partially known. The studies have shown that HS enhance root, leaf and shoot growth but also stimulate the germination of seeds of various crop species.

The addition of HS stimulate nutrient uptake, cell permeability and seems to regulate mechanisms involved in plant growth stimulation. Some of their positive effects may be ascribed to a general improvement of soil fertility, leading to a higher nutrient availability for plants. While in other cases, HS seem to positively influence metabolic and signalling pathways involved in the plant development by acting directly on specific physiological sites of action.

There are three main fractions of humic substances namely humic acid (HA), fulvic acid (FA) and humin. The HA and FA are extracted from soil and other solid phase sources using a strong base (NaOH or KOH). Humic acids are insoluble at low pH, and they are precipitated by adding strong acid (adjust to pH 1 with HCl). Humin cannot be extracted with either a strong base or a strong acid. Humic acid is the most complex form of organic material and it is a ready source of carbon and nitrogen and known as the black gold of agriculture and is increasingly becoming popular for use in agriculture. Humic acid is the major extractable component of soil humic substances having dark brown to black in colour. It is a composite of smaller units such as aliphatic and aromatic groups, oils, phenolic esters, fatty acids, alkanes, tannins, monosaccharides and polysaccharides (Harper *et al.*, 2000).



Conclusion

The integrated use of organic manures and inorganic fertilizers not only increases the efficiency but can help in the substitution of chemical fertilizers. The use of HA is a promising natural resource to be utilized as an alternative for increasing crop production. Nowadays, humic acid is extracted on a large scale from various sources and their exact composition varies from one source to another. The organic waste materials mainly of animal and plant origin are potential source of organic matter and plant nutrients. The benefits derived from the utilization of these organic materials range from improvement of soil fertility to a reliable means of waste disposal.

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IOT SENSORS TO MONITOR SOIL FERTILITY

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Introduction

Agriculture is a crucial sector of the Indian economy and is considered the backbone of the country. Around 60% of India's population is engaged in agriculture, and it contributes for organic and eco-friendly products in the global market, the Indian agriculture sector is expected to grow even further (Acharya *etal* 2020). For growing population and increasing demand to food, there is a pressing need to increase agricultural productivity to meet the rising demand. Improved productivity in agriculture can be achieved through the adoption of modern technologies like precision farming techniques and the use of fertilizers and pesticides. Precision agriculture, also known as precision farming, is an approach to farming that uses technology and data analytics to optimize crop production and resource management. It involves the use of sensors and other advanced technologies to collect and analyze data about soil conditions, crop growth, and other factors that affect agricultural productivity. Nowadays farmers and agricultural companies are turning to the Internet of Things (IoT) to meet demand. Since we need to continuously take measures manually it requires large amount of time. So using this Smart Agriculture we can effectively take the measurements in less amount of time.

In this sensors can provide continuous measurements with respect to climate changes. Using Internet of things we can produce different ways to cultivate soil. Smart Agriculture and Smart Farming applications will help the farmer with 24/7 visibility into soil, crop health, and energy consumption level. IoT sensors can measure the soil temperature, moisture, sodium (N), potassium (K), phosphorous (P), photosynthetic radiation, oxygen levels, and soil water potential. The data from IoT sensors are transmitted back to the central point for measuring soil

fertility, visualization, and trend analysis. The resultant data is used to optimize farming operations, identify trends, and enhance crop yield quality. There are various sensors to help the farmers to monitor soil conditions.

1. Ground - Based Sensor

Ground based sensors is needed for soil organic matter, soil moisture, cation exchange capacity, nitrate nitrogen, compaction, soil texture, salinity level, weed detection and crop residue coverage. These parameters as well as soil pH and availability of phosphorus and potassium cannot be ascertained by remote sensing technology. Moreover, the use of real - time ground - based sensors provides the grower control over timing of data acquisition not possible with satellite or aircraft sensing techniques.

2. Soil Temperature sensor

Soil temperature is a crucial aspect of belowground plants. This influences root growth, decomposition, respiration, and mineralization of nitrogen. IoT sensors estimate soil temperature by measuring the air temperature and other factors, but the most accurate measurement is using a probe buried in the soil. Based on the root structure of the plant, the probes can be installed at different depths. The surface soil temperature is measured with a different type of IoT sensor that uses IR technology. IoT-enabled sensors such as thermocouples or RDs are installed to measure temperature in critical areas of a premise. The specialty of these sensors is that they can transfer data directly to IoT platforms without any complex systems. This data is later analyzed and displayed on the dashboard or mobile apps.



Soil Temperature / Humidity tester Plant monitor sensor

3. Soil Moisture sensor

Soil moisture content is a crucial element that determines soil fertility. Measuring soil moisture is a part of measuring soil fertility. Soil moisture sensors measure the water content in the soil at various depths. They help farmers determine when to irrigate and how much water to apply, optimizing water use efficiency and preventing water stress or water logging in crops. The soil moisture sensor uses capacitance to measure dielectric permittivity of the surrounding medium. In soil, dielectric permittivity is a function of the water content. The sensor creates a voltage proportional to the dielectric permittivity, and therefore the water content of the soil.



Soil Moisture Sensor with Arduino – Automatic Plant Irrigation System

4. Nutrient Sensor

Soil nutrient detection sensor is a device used to measure the concentration of various nutrients in the soil, which is vital for plant growth and agricultural productivity. These sensors play a vital role in precision agriculture, helping farmers make informed decisions about fertiliser application rates, adjust nutrient management practices, and prevent over - fertilization or nutrient runoff, thereby reducing environmental impact and production costs.

5. NPK sensor

Precision Fertiliser application helps to monitoring real-time data of nutrients in the soil through NPK sensors to help farmers accurately, calculate the amount of fertiliser to be applied and reduce wastage and evaluates the long-term fertility of the soil and provides a basis for soil improvement. There are many benefits to farmers by using NPK sensors in the field (i.e) Increase Crop field, Cost saving. In case of development, NPK sensors are integrated with

other soil sensors (e.g. soil temperature and humidity, pH sensors) to provide more comprehensive soil data and also to facilitate rapid soil nutrient testing by farmers in the field.

6. Gas Sensor

Gas sensor detect gases such as carbon dioxide (CO_2), methane (CH_4) and ammonia (NH_3) emitted from soil. They help farmers monitor soil microbial activity, assess crop respiration rates and manage greenhouse gas emissions in agricultural systems.

7. Optical sensor

This sensor used light to measure soil properties and has to develop to determine clay, organic matter and moisture content of the soil.

8. Electrochemical sensor

This sensor can detect a variety of chemical characteristics in the soil or water, including salinity and oxygen levels, which are critical for crop health.

9. Infrared sensor

This sensor measure surface temperature can be used to monitor crop health, detect water stress and assess soil conditions.

10.pH sensor

A soil pH sensor for IoT (Internet of Things) is a device designed to measure the pH level of soil in real-time and transmit the data wirelessly to an IoT platform or system. pH sensors measure the acidity or alkalinity of soil and water samples. They help farmers assess soil fertility, determine lime application rates, and maintain optimal PH levels for crop growth and nutrient availability.



Soil pH sensor to test plant nutrients



In conclusion, sensors for soil monitoring are important tools for modern agriculture to help farmers make data-driven decisions, promote sustainable agricultural practices, enhance crop health, and maximise yields. The use of sensors in precision farming not only improves data quality, lowering costs associated with inputs such as water and fertilizer. As technology continues to advance, these sensors are becoming more accurate, reliable and accessible, further improving agricultural productivity and minimizing environmental impact.



OPTIMIZATION OF FYM APPLICATOR FOR ACCURATE RATE AND BAND WIDTH DELIVERY

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Abstract

Due to the increased shortage of agricultural labor during peak seasons, farmers face significant challenges in applying farmyard manure (FYM) efficiently. To address this, a tractor-drawn FYM applicator integrated with a seed planting facility was designed, developed, and modified in the Farm Machinery Department workshop at SVCAET&RS, IGKV, Raipur. This implement ensures uniform distribution of FYM and seeds in accurate quantities and proper bands across the field. An agitator-type metering unit was incorporated to break down the FYM within the hopper. This paper presents a laboratory evaluation of the applicator, focusing on FYM application rate and band width. A linear relationship was observed between forward speed, moisture content, orifice opening, and these parameters.

Keywords: Application rate, band application, farmyard manure, FYM applicator cum planter, grain yield, operational cost.

Introduction

Manure is an excellent and valuable substitute for commercial fertilizer. FYM is used to improve soil fertility. Organic farming improves the soil health by improving the physical properties, increasing soil aggregation, water holding capacity, hydraulic conductivity etc. (Singh and Thomas, 2010). FYM supplies organic materials to the soil together with plant available nutrients nitrogen, phosphorus and potassium (NPK). It increases microbial biomass, carbon content and an enzyme compared to inorganic fertilizer (Lauge *et al.* 2006). Organic wastes are beneficial in improving crop yield, soil pH, organic carbon and available NPK in soil (Hansen *et*

al., 2004). When properly managed, land application of manure is also an environmentally sound way to recycle livestock by-products. Surface and groundwater contamination can be reduced by using appropriate equipment. Improve air quality and decrease greenhouse gas emission can achieve by controlled application of manure. Farmyard manure (FYM) is mainly being applied through manual broadcasting, resulting more labours and time per unit area with poor application uniformity and wide variation of application rate. Use of manpower for application of organic materials is uneconomical due to high labor cost. Thus, it attracted wide attention in various parts of world (Kunal *et al.*, 2018). Solid stack piled manure losses about 21 % of its nitrogen to the atmosphere (Lauge *et al.*, 2006; Singh and Singh, 2014). Commercial equipments are not distributed the manure uniformly and having large coefficient of variation (Hansen *et al.*, 2004; Thirion *et al.*, 1998; Wilhoit *et al.*, 1993).

Exposure of manure in air releases the ammonia and greenhouse gases. Immediately covering the manure within the soil should be necessary with harrowing or some other technique (Sapkale *et al.*, 2010). Availability of mechanical device for spreading farmyard manure is not commercialized in India (Dhaiwal and Vinay, 2004; Suthakar *et al.*, 2008). Sowing of crops is the further next operation in the field of broadcasted FYM which added extra cost and energy whereas resulted in reduced crop yield, returns and wastage of FYM in excess amount. Therefore a tractor drawn FYM applicator cum planter system is required for proper application of FYM in band form within row for the increasing the crop productivity.

MATERIALS AND METHODS

Design consideration

Theoretical design consideration of tractor drawn FYM applicator was taken on the basis of agronomical, functional and economical consideration. The overall dimensions of FYM applicator was 2415×1500×1350 mm. The capacity of FYM hopper (2000×600×720 mm) as shown in Fig.1 was 302 kg at moisture content of 31% dry basis. The FYM applicator had agitator mechanism. This mechanism is driven through drive wheel of applicator. Agitator mechanism crushes the FYM and moves it to the orifice to deliver the furrow opener. There is provision for varying the application rate on slider plate. Area of orifice was adjusted by slider plate. Inclined metering mechanism was developed for planting unit. When the forward movement of the machine occurs, the drive gear rotate along with the wheel so by that the driven

gears also rotates (Jayamurthy *et al.*, 2018). Inclined plate was driven through chain and sprocket mechanism and get power from drive wheel.

Total nine numbers of agitators are provided for each furrow opener. The length and diameter of agitator was 116 and 145 mm, respectively. Six numbers of triangle agitator plates occupies on periphery of agitator shaft. Angle between two triangle plates was 60°. The spacing of agitators was fixed by spool in the agitator shaft. Square shape spools were provided on the periphery of agitator shaft having 40 mm sides dimension. Two continuous agitators were set at the difference of 30° angle between their M.S. plates. Speed of rotation of agitator was 0.6 times of the ground wheel. The agitator breaks down of manure clods at the impact velocity of 0.2 to 1.5 m/s. Inclined plate diameter was 170 mm. The opening and depth of groove of inclined plate was 9 and 9 mm, respectively such that two to three seeds were loaded for rice because they are cylindrical in shape. The bottom of the groove had a radius of 2 mm. The brush helps to remove any seed or foreign particle that gets stuck in the grooves.

During field testing 50 HP tractor was used. The specifications of the tractor used for present study are given below in Table 1.

Table 1. Specifications of the tractor used to drive FYM applicator cum planter	
Specifications of Tractor	
Type	DI, 4 stroke, Diesel
Steering	Power Steering
No. of cylinders	3
Horse Power	50
Rated RPM	2200
Transmission	Fully constant mesh gear box
Drive	2 WD
No. of gears	8F+2R
Maximum forward speed	39 Kmph
PTO HP	48 HP
No. of splines	6
PTO rpm	540@1600 Erpm

The FYM applicator was attached to three point hitch of tractor through three point hitch link. The drive from ground wheel of applicator had been given to the agitator shaft through main shaft of applicator. Agitator shaft rotate the agitator provided on periphery as shown in Fig.2.



Fig.1. Stationary view of tractor operated FYM manure applicator with agitator unit



Fig.2. View of agitator unit

FYM applicator was attached to tractor with three point linkage. Ground wheel was provided to transmit the power from tractor to FYM applicator. Chain and sprocket mechanism was used to transmit the power from ground wheel to agitator unit of FYM hopper. Different orifice opening was provided bottom side of FYM hopper. Planting unit was attached behind of FYM hopper. Inclined metering mechanism was used to meter the seeds in seed box. A set of sprocket was provided to regulate the seed spacing. Tractor operated farmyard manure applicator with a provision of planting unit was filled with farmyard manure upto its full capacity for each experiment and rice seeds in seed box. The experiment was conducted at different forward speed, moisture content and orifice opening. Tractor was operated at forward speed varying from 2.0 to 6.0 km/h, moisture content of 33 to 21 % (db) and 1/4th to full orifice opening. The parameters recorded were FYM application rate (t/ha) and FYM band width (mm).

RESULTS AND DISCUSSION

The capacity of tractor operated FYM applicator with a provision of planting attachment varied with the moisture content of farmyard manure. The tractor operated FYM applicator with a provision of planting attachment was operated in the laboratory at different forward speed, moisture content and orifice openings and data recorded are shown in Table 2 and Table 3.

Application rate

Tractor drawn prototype FYM applicator cum planter was calibrated in laboratory. Desired FYM application rate was adjusted by the orifice opening position of applicator viz. 18, 36, 54 and 72 mm as 1/4th, 1/2th, 3/4th and full, respectively. Laboratory test was taken at 31% db, 21% db and 13% db FYM for application rate and band width. Experiments were conducted between forward speeds varying from 2 to 6 km/h.

Table 2 Obtained mean application rate and results of ANOVA table for application rate of the selected parameters during laboratory test

	A ₁				A ₂				A ₃			
	B ₁	B ₂	B ₃	B ₄	B ₁	B ₂	B ₃	B ₄	B ₁	B ₂	B ₃	B ₄
C ₁	6.21	8.633	15.13	20.40	7.12	10.02	16.89	23.24	8.11	11.32	19.58	24.93
C ₂	3.17	6.830	13.85	17.85	3.65	7.35	14.96	19.54	4.14	8.76	16.80	20.40
C ₃	1.77	5.06	10.51	14.84	2.06	5.63	12.68	16.85	2.26	6.52	12.85	17.21
	CD (p<0.01)								SE(m)			
Factor(A)	0.100								0.036			
Factor(B)	0.116								0.041			
Intrraction A X B	0.201								0.071			
Factor(C)	0.100								0.036			
Intrraction A X C	0.174								0.062			
Intrraction B X C	0.201								0.071			
Intrraction A X B X C	0.348								0.123			

A₁= 13per cent db, A₂ = 21per cent db, A₃ = 31per cent db, B₁= 1/4th opening, B₂ = 1/2nd opening, B₃ = 3/4th opening, B₄ = full opening, C₁= 2 km/h, C₂ = 4 km/h, C₃ = 6 km/h, A= Moisture content (per centdb), B = Orifice openings, C = Forward speed of tractor

It is clear from Table 2 that as the orifice opening level and moisture content levels were increased, the FYM application rate increased. The increase in manure delivery rate with increase in opening area of delivery slot was due to availability of more area, allowing increased quantity of manure to pass through was reported by Patil and Munde (2017) and Naveenkumar *et al.*, (2017).

Overall increasing forward speed of tractor resulted in increase into field capacity of machine but decrease in manure application rate per unit area. Therefore the effect of moisture content, orifice opening and forward speed were individually and in combination, was significant ($p < 0.01$) on FYM application rate.

Band width

These data shows that the FYM band width increased with increase in orifice opening position. Similar trend was observed at all three moisture content followed by all three forward speeds. These results were concluded that the band width values were decreased at increasing forward speed. Same results were observed at all three moisture content and all four orifice openings. These values were concluded that FYM band width values decreased at increasing moisture content. This result was found due to dried particles are more shattered as compare to the moist particles. The effect of orifice opening, forward speed and moisture content were individually significant but their combination was non-significant on FYM band width as shown in Table 3. Orifice openings, forward speed and moisture content were individually affected the band width at ($p < 0.05$) significant.

Table 3 Obtained mean band width and results of ANOVA table for FYM band width of the selected parameters during laboratory test

	A ₁				A ₂				A ₃			
	B ₁	B ₂	B ₃	B ₄	B ₁	B ₂	B ₃	B ₄	B ₁	B ₂	B ₃	B ₄
C ₁	35	57	91	115	34	55	90	110	33	53	87	110
C ₂	33	54	80	102	32	53	81	100	31	51	77	97
C ₃	32	52	76	100	30	49	71	90	29	46	71	90
	CD ($p < 0.01$)								SE(m)			
Factor(A)	2.057								0.729			
Factor(B)	2.375								0.842			
Intraction A X B	N/A								1.459			
Factor(C)	2.057								0.729			
Intraction A X C	N/A								1.264			
Intraction B X C	4.114								1.459			
Intraction A X B X C	N/A								2.527			

$A_1 = 13\text{ per cent db}$, $A_2 = 21\text{ per cent db}$, $A_3 = 31\text{ per cent db}$, $B_1 = 1/4^{\text{th}}$ opening, $B_2 = 1/2^{\text{nd}}$ opening, $B_3 = 3/4^{\text{th}}$ opening, $B_4 = \text{full opening}$, $C_1 = 2 \text{ km/h}$, $C_2 = 4 \text{ km/h}$, $C_3 = 6 \text{ km/h}$, $A = \text{Moisture content (per centdb)}$, $B = \text{Orifice openings}$, $C = \text{Forward speed of tractor}$

Conclusion

Agitator type FYM metering unit can easily crush the farmyard manure and deliver it to the orifice. FYM applicator can apply FYM in band form with their surface incorporation in soil. Application rate was affected by FYM tractor forward speed, FYM moisture content and orifice opening position. The FYM applicator can be operated to achieve desired FYM application rate by increasing or decreasing the orifice openings. Higher manure application rate could be achieved by full opening position of orifice. Combination of FYM moisture content, orifice opening position and tractor forward speed were non significant affect on FYM band width.

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MARICULTURE OF CORALS – AN UPCOMING AREA OF RESEARCH

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Abstract

The marine ornamental industry is a thriving multimillion-dollar business, with live corals ranking among the most sought-after organisms. However, the high demand places significant harvesting pressure on coral reefs, prompting increased attention to coral aquaculture as a viable solution to mitigate this impact. Reports say that nearly 77% of the world's coral reef areas from the Atlantic to the Pacific to the Indian oceans, suffer from bleaching due to heat stress. Data from the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) between 2011 and 2015 indicates that 74.7% of the global live coral trade originates from wild harvests, while only 26.3% comes from captive breeding. Efforts to cultivate live corals in controlled environments have been ongoing for decades, though reports of consistent success remain limited. This article gives an overview of the history, candidate species and culture technology of marine corals.

Keywords: Fraggling, Coral propagation, Polyps, Marine ornamentals

Introduction

Since the late 1980s, home aquariums featuring live corals have grown significantly in popularity. Before 1986, maintaining coral aquariums was primarily a European practice, concentrated in countries like Germany, Austria, Belgium, the Netherlands, and Scandinavia. One of the earliest efforts in coral cultivation occurred at the Noumea Aquarium in New Caledonia. As early as 1956, the aquarium displayed field-collected corals in outdoor systems illuminated by natural sunlight. European hobbyists also played a key role in advancing coral propagation. In 1973, Peter Wilkens documented techniques for propagating both stony and soft

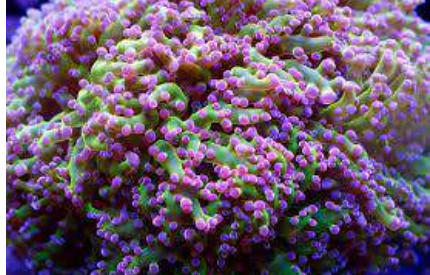
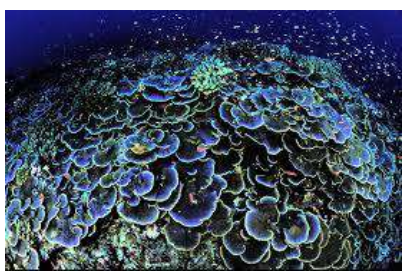
corals. In the 1980s, Dietrich Stüber, a hobbyist in Berlin, Germany, successfully cultivated *Acropora* sp. from a small fragment attached to a live rock. Although coral propagation has been practiced for decades, research into advanced techniques and the factors influencing success only began in earnest during the 2000s and remains an area of active exploration. In India, Studies on the propagation of soft coral *Cladiella laciniosa*, *Dampia pocilloporaeformis* were continued at Mandapam and *Sinularia kavarattiensis* at Mandapam and Calicut by Central Marine Fisheries Research Institute, Kochi in 2016.

Coral species for aquaculture:

The following table provides the list of various commonly used coral species in the aquaculture industry.

Table 1: Common coral species suitable for aquaculture

S.No.	Genera	Growth type	Common name(s)
1.	<i>Acropora</i>	Branching	Staghorn coral
2.	<i>Euphyllia</i>	Phaceloid or flabello-meandroid with fleshy polyps	Hammer coral, frogspawn, torch coral
3.	<i>Montipora</i>	Plating, branching or encrusting	Montipora coral
4.	<i>Caulastrea</i>	Phaceloid with fleshy polyps	Trumpet coral or candycane coral
5.	<i>Goniopora</i>	Massive or submassive hemispherical or irregular; typically with fleshy collumellae	Goniopora or flower pot coral
6.	<i>Echinophyllia</i>	Plating	Chalice coral
7.	<i>Turbinaria</i>	Encrusting or laminar	Cup coral, disc coral
8.	<i>Hydnophora</i>	Submassive, encrusting or branching	Horn coral
9.	<i>Pocillopora</i>	Branching	Cauliflower coral
10.	<i>Stylophora</i>	Blunt branching or encrusting	Stylophora coral or birdsnest coral

		
<i>Acropora</i> sp.	<i>Euphyllia</i> sp.	<i>Montipora</i> sp.
		
<i>Caulastrea</i> sp.	<i>Goniopora</i> sp.	<i>Echinophyllia</i> sp.
		
<i>Turbinaria</i> sp.	<i>Hydnophora</i> sp.	<i>Pocillopora</i> sp.

Source: <https://en.wikipedia.org/>

Aquaculture Systems for Corals:

Coral aquaculture can be performed in situ or ex situ (in open or closed systems).

I. **In situ aquaculture**, also known as mariculture, is the culture of organisms (corals in the case of this review) in their local environment, e.g., corals that are cultured in tropical waters near to the reef ecosystems.

In these systems, the corals are believed to be both subject to the optimal conditions and benefiting from the elements essential for growth, which are produced within this ecosystem. Despite these advantages, in situ coral cultures suffer from of natural stressors including predation, competition, pollution, storms and also natural disease outbreaks.

Advantages:

- Relatively low culture costs, as the environment freely supplies food, water and energy essential to coral growth.

Disadvantages:

- Control of abiotic and biotic factors is fairly limited and is mainly controlled by natural factors
- Natural and anthropogenic features, such as physicochemical environmental impacts, predators, competitors and pollutants may hinder coral production.

II. **Ex situ coral aquaculture** in contrast, is the culture and propagation of corals outside of their natural habitat. Ex situ cultures may be performed in either recirculating aquaculture systems (RAS), which may in some cases be very distant from the nearest marine environment, or may be near marine environment, pumping natural sea water into their system and are then usually termed flow-through aquaculture systems (FTAS). The advantage of this system is that it can be manipulated and controlled to maximize coral production and guarantee the successful husbandry of corals. On the other hand, corals reared in FTAS are cultured in natural ambient conditions that are presumably optimal for their growth and health.

Advantages:

- Better control on the water system by manipulation of input water and preventing any potential problem associated with maintaining the corals in natural seawater.

Disadvantages:

- Production costs associated with ex situ propagation can be considerable and be a potential constraint to the economic viability of this practice.
- deterioration of water quality following long term use in completely closed recirculating systems (RAS).
- If the system is not properly monitored or properly filtered, it may become low in nutrients and may have missing elements necessary for coral growth such as strontium, calcium and magnesium.

Coral propagation:

Coral propagation can either be performed in situ or ex situ, with in situ propagation significantly reducing production costs. Unlike ex situ propagation, corals propagated in their

natural environment do not require any adaption to captive stocking conditions. Propagation of corals, particularly through asexual reproduction or ‘fragging’, is a simple process and does not require elaborate equipment or specialised skills.

Asexual propagation:

High wave activity and other physical disturbances often fragment colony branches or break portions of colonies in a process known as fragmentation. Fragments have the ability to reattach to a new substratum and grow into new colonies. Fragments similar to those resulting from natural physical disturbances can be produced in land-based culture facilities (ex situ) and in the wild on coral reefs (in situ) for a range of purposes. Brood stock or donor coral colonies for fragmentation are predominantly sourced from local wild stocks. Although colonies can be fragmented without translocation of donor colonies, frequently whole colonies are removed from the substratum with a hammer and chisel for translocation to the in situ or ex situ nursery where acclimatization or acclimation, respectively, takes place prior to fragmentation.

Sexual propagation:

Sexual propagation protocols have developed considerably over the last 15 years, with successful techniques established for both brooding and broadcast spawning species. This can be done in two ways:

- i) Gametes from broadcast spawning corals and brooding corals can be collected in situ by positioning non-invasive collection devices around individual colonies.
- ii) Alternatively, corals can be harvested prior to spawning events and maintained in hatcheries.

Water quality parameters:

The desirable range of water quality parameters include:

Desirable range of water quality parameters in coral culture

S.No.	Parameter	Values
1.	Temperature	26 ± 0.5 °C maintained using heat pump
2.	Salinity	35.9 ± 0.57 ppm
3.	pH	8.27 ± 0.11
4.	Light	Superficial photosynthetically active radiation (PAR) of 640.4 ± 311 $\mu\text{mol photons m}^{-2} \text{s}^{-1}$ at coral fragment level, at 12:00 PM

5.	Ammonia	0.03 ± 0.03 mg/l N
6.	Nitrate	0.01 ± 0.02 mg/l N
7.	Nitrite	0.002 ± 0.001 mg/l N
8.	Phosphorus	0.03 ± 0.01 mg/l PO ₄
9.	Alkalinity	135 ± 15 mg/l CaCO ₃
10.	Calcium	405 ± 45 mg/l CaCO ₃

Feeding

No corals are documented to exhibit complete autotrophy, heterotrophy provides essential organic nutrients necessary for coral growth and development. Corals feed on plankton, bacteria, and particulate organic matter, and they even absorb dissolved nutrients from the water. It reported that mucus produced by polyps was one of the major mechanisms to enhance heterotrophy feeding of corals. Artemia because it is a commonly used live food in aquaculture facilities well accepted by several corals species and specifically by *D. axifuga*. Lipid-enriched Artemia was used because it improves overall coral health. Enhanced growth of *P. damicornis* was noticed when fed the rotifer *Branchionis* sp., and the marine diatom *Tetraselmis suecica*, although growth rates were lower than those fed Artemia nauplii. Alternatively, engineered coral food, for example powdered plankton has been used to successfully supplement the diets of coral juveniles.

Commonly encountered diseases, Control and treatment:

Aspergillosis, Atramentous necrosis, Bacterial bleaching, Black band disease, Dark spots syndrome, Trematodiasis, Skeleton eroding band, White syndrome, etc are some of the commonly encountered diseases in corals.

Control and treatment:

1. Keeping corals in replicate systems isolated from one another would therefore inhibit disease spread between systems.
2. Coral culture systems could be either completely isolated or semi-isolated (separated water source and culture tanks or culture tanks separated after the filtration system respectively).
3. Sufficient filtration and sterilisation of all incoming water and quarantine for all other inputs. Filtration can be chemical (such as activated carbon), mechanical (filters) or biological (live rocks), whereas sterilisation is commonly performed using UV light or through ozonation.

4. Quarantine duration depends largely on the host organism being treated and/or the pathogen of concern. However, the use of prophylactic treatments should be avoided during quarantine, unless pathogen screening has identified a known pathogen for which an effective treatment exists.

5. Functionally diverse fish communities minimise coral disease development through the control of corallivorous fish which exacerbates disease development.

Conclusion

Coral propagation provides a vital opportunity for sustainable livelihood diversification in island communities, empowering locals to engage in the ornamental coral trade or contribute to reef restoration initiatives. Current cost assessments indicate that asexual propagation techniques are the more economical option, but improvements in sexual propagation and nursery practices could alter this trend in the future. Breeding programs can focus on selecting favorable traits such as faster growth, greater disease resistance, increased thermal tolerance, and improved survival rates, thereby boosting the resilience and viability of corals cultivated for the ornamental trade.

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FROM SEED TO HARVEST: MASTERING OKRA FARMING

Article ID: AG-VO5-I05-19**Sonam Tripathi¹, Manshi Awasthi² and D. K. Upadhyay^{3*}**

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Abstract

Okra is a highly nutritious vegetable with numerous health benefits. Consuming an adequate amount of quality vegetables is essential for maintaining overall health. A general review of okra was conducted to enhance awareness regarding its cultivation, utilization, and the need for further research. Understanding factors such as climate, soil fertility, field management, and health benefits plays a crucial role in promoting okra production and consumption. Okra is predominantly grown in tropical and subtropical regions, thriving in warm climates with an annual rainfall of 900–1,000 mm and temperatures ranging between 18°C and 35°C. It grows best in sandy or clay loam soils with a pH of 6.0 to 7.0. For optimal growth and yield, okra generally requires 150 kg of nitrogen, 112 kg of phosphorus, and 75 kg of potassium per hectare. Proper plant population is essential for maximizing productivity, which is typically achieved with a spacing of 50 cm × 40 cm. However, various pests and diseases, such as okra yellow vein mosaic virus, okra enation leaf curl virus, and fruit borers, pose significant challenges, leading to reduced yield and lower quality produce. Despite these constraints, okra is increasingly recognized for its nutritional and medicinal properties. Its leaves, pods, and seeds are all edible and highly nutritious. Okra leaves exhibit anti-inflammatory, anti-hyperglycemic, anti-hyperlipidemic, and antioxidant properties, making it beneficial for overall health. This review highlights key aspects of okra cultivation, including climate requirements, field management

practices, and its nutritional and medicinal benefits. Raising awareness about proper cultivation techniques and the health advantages of okra can encourage farmers, agricultural stakeholders, and health professionals to support its production and consumption.

Introduction

The Latin name for okra is *Abelmoschus esculentus* (L.) Monech, commonly known as lady's finger or bhindi, is a vital vegetable crop belonging to the family Malvaceae. Vavilov (1926), proposed its origin in the Abyssinian center. It is widely cultivated in tropical and subtropical regions worldwide, particularly in India, Nigeria, Sudan, and Pakistan (Dantas, et al. 2021). Okra serves as a multi-purpose crop, primarily grown for its tender green fruits, which are consumed as a vegetable in various culinary preparations. These fruits are rich in essential vitamins, minerals, and dietary fibers including significant amounts of vitamins A, C, K, and B complex, calcium, potassium, and magnesium which many times are not available in the common food of people living in developing nations. It plays then an important role in the human diet (Ndunguru & Rajabu, 2004). Okra seeds can be processed by drying and milling in flour, are very rich in protein and oil. Okra leaves are considered good cattle feed, but this is seldom compatible with the primary use of plant. The leaf buds and flowers are also edible. Notably, Carbohydrates are mainly present in the form of mucilage (Kumar *et al.*, 2009) in okra pods is known to promote digestive health and aid in regulating blood sugar levels, making it particularly advantageous for individuals with diabetes (Dantas *et al.*, 2021). Additionally, the crude fiber present in the mature fruits and stems has applications in the paper industry, further diversifying the crops utility. Agronomically, okra is a hardy, fast-growing crop that thrives in warm and humid climates.

Okra exhibits significant genetic variability in traits such as plant height, fruiting pattern, pod size, yield, and disease resistance, making it an important subject for breeding programs aimed at improving productivity and quality (Ahmad *et al.*, 2016). Despite its economic importance, okra cultivation faces several challenges, including susceptibility to pests like fruit borers, jassids, whiteflies, and diseases such as yellow vein mosaic virus (YVMV) and powdery mildew. Efforts to enhance genetic resistance through breeding and biotechnology approaches are crucial for sustainable okra production. Additionally, research on optimizing cultural practices, nutrient management, and post-harvest handling can further improve the yield and marketability of okra.

Importance

Okra is a highly nutritious vegetable with multiple uses and health benefits. It is primarily consumed for its tender green pods, which are rich in vitamins (A, C, and K), minerals (calcium, potassium, and magnesium), fiber, and antioxidants. The pods are commonly used in soups, curries, stir-fries, and stews due to their mucilaginous texture, which also acts as a natural thickening agent in cooking. Okra seeds are a good source of oil and protein, with high levels of unsaturated fatty acids like linoleic acid, beneficial for heart health. Additionally, okra fiber supports digestive health, promotes gut motility, and helps in weight management. The soluble fiber in okra aids in regulating blood sugar levels, making it beneficial for diabetics by slowing glucose absorption (Dubey *et al.*, 2017). It also has potential cholesterol-lowering effects, reducing the risk of cardiovascular diseases. Rich in antioxidants such as flavonoids and polyphenols, okra helps combat oxidative stress and inflammation, supporting immune function and reducing the risk of chronic diseases. Studies suggest that okra may have anti-cancer properties due to its bioactive compounds that inhibit cancer cell growth. Furthermore, okra is known for its neuroprotective effects, potentially benefiting brain health and reducing the risk of neurodegenerative disorders like Alzheimer's. Its mucilage content is soothing for the digestive tract, making it useful for individuals with gastritis or ulcers. In traditional medicine, okra has been used to treat respiratory issues, skin ailments, and anemia due to its iron and vitamin C content. Overall, okra is a versatile, health-boosting vegetable with applications in both culinary and medicinal fields (Torkpo *et al.*, 2008).

Botanical Classification:

Kingdom: Plantae

Phylum: Angiosperms

Class: Eudicots

Order: Malvales

Family: Malvaceae

Genus: *Abelmoschus*

Species: *Abelmoschus esculentus*

Origin and Cytogenetic relationship

Okra plant or lady finger was previously included in the genus *Hibiscus*. Later, it was designated to *Abelmoschus*, which is distinguished from the genus *Hibiscus* (Aladele *et al.*,

2008). *Abelmoschus* was subsequently proposed to be raised to the rank of distinct genus by Medikus in 1787. Okra originated somewhere around the Ethiopia, and was cultivated by the ancient Egyptians by the 12th century. Its cultivation spread throughout Middle East and North Africa. There is a significant variation in the chromosome numbers and ploidy levels in *Abelmoschus*. The highest chromosome number reported are close to 200 for *A. manihot* var. *Caillei*, whereas the lowest chromosome numbers reported is $2n=56$ for *A. angulosus* (Ford 1938, Siemonsma 1982). Most of the cultivated varieties are amphidiploids with $2n=130$. *A. esculentus* is noted for its chromosome polymorphism and $2n$ ranges from 72 to 144. It tolerates addition or deletion of one or a few chromosomes.

Soil Requirements

Okra can be grown in wide range of soils. However, it grows best in loose, friable, well-drained, sandy loam soils free from hard pan is the best, with a pH range of 6.0–7.0, while alkaline, saline, and poorly drained soils are unsuitable for its cultivation. Due to its deep taproot system, a minimum soil depth of 60–90 cm (24–36 inches) is necessary for optimal growth. High organic matter content, such as compost or manure, enhances soil fertility and structure, promoting better plant development. Additionally, adequate availability of essential nutrients, particularly nitrogen, phosphorus, and potassium, is crucial for healthy growth and high yields.

Climatic Requirements

Okra thrives best in temperatures ranging from 24–32°C (75–90°F), with seed germination requiring a minimum soil temperature of 21°C (70°F). Highly sensitive to frost, it cannot tolerate cold conditions. For optimal storage, fresh okra should be kept at 7–10°C (45–50°F) and can remain fresh for 7–10 days, while drying can be done at 60°C (140°F) for preservation. Consistent moisture is essential, especially during flowering and fruiting stages, with an ideal rainfall or irrigation requirement of 900–1,000 mm per growing season. Okra requires full sun, needing at least 6 hours of direct sunlight daily, and prefers a relative humidity of 60–80% for optimal growth. In tropical regions, it can be cultivated year-round with frequent watering and fertilization, while in subtropical and temperate regions, it is grown as a summer crop, typically planted in late spring to early summer. Okra can also be successfully grown during the rainy season, even in areas with heavy rainfall, but it remains highly susceptible to frost damage, and seed germination does not occur when temperatures drop below 20°C. Okra is highly sensitive to extremely low temperatures and frost, with an optimal temperature range of

24°C to 28°C for normal growth and development (Chittora et al., 2017). At 24°C, the first flower bud typically appears in the third leaf axil, whereas at 28°C, it may develop at the sixth leaf axil. However, this higher position does not necessarily indicate a delay in flowering, as increased temperatures accelerate plant growth, allowing the higher node to be reached sooner. While higher temperatures further enhance growth, they may also slightly delay fruiting. Additionally, okra plants tend to grow taller during the rainy season compared to the warm season. The optimal reproductive phase in okra occurs when the average daytime temperature ranges between 25-35°C. However, temperatures exceeding 42°C during flowering and pod-filling stages can severely impact reproductive organs, leading to flower drop, pollen sterility, pod abortion, and a reduced seed count. This ultimately results in diminished growth and yield (Tripathi et al., 2011; El-Shaieny and Bashandy, 2022).

The crop coefficient values of okra vary throughout its growth stages, starting lower at the seedling stage and gradually increasing as the plant develops, peaking during flowering and pod-setting before declining toward maturity (Patil, 2010). These values also differ across seasons due to variations in climate and crop growth conditions. On average, okra requires a total water supply of 547.4 mm during its growth cycle, though this amount may fluctuate depending on weather conditions (Patil, 2010).

Important Varieties and Hybrids

Popular Okra Varieties

Okra features a range of varieties and hybrids that are recognized for their high yield, adaptability, and resistance to significant diseases such as Yellow Vein Mosaic Virus (YVMV) and Okra leaf Curl Virus (OLCV). Here is a categorized list of some of the notable ones:

Open Pollinated Varieties

Variety	Key Traits	Developed by
Prabhani kranti	YVMV resistant; dark green, slender fruits; yield: 8.5-9 t/ha	VNKMV, Prabhani
Arka Anamika	YVMV resistant; medium-long, tender fruits; yield: 12-15 t/ha	IIHR, Bengaluru
Pusa Sawani	YVMV resistant; suitable for all seasons; yield: 12-15 t/ha	IARI, New Delhi

Pusa A-4	YVMV resistant; dark green fruits; yield: 10-12 t/ha	IARI, New Delhi
Pusa Bhindi-5	YVMV resistant; dark green, 5-ridged fruits; yield: 18 t/ha	IARI, New Delhi
Kashi Chaman	YVMV & OELCV tolerant; suitable for summer and rainy seasons; high yield	ICAR-IIVR, Varanasi
Kashi Pragati	High yield; superior fruit quality	ICAR-IIVR, Varanasi
Kashi Lalima	Excellent yield and fruit quality	ICAR-IIVR, Varanasi
Kashi Vardaan	High-yielding; quality fruits	ICAR-IIVR, Varanasi
Kashi Vibhuti	YVMV & OLCV resistant; dwarf variety; yield: 17-18 t/ha	ICAR-IIVR, Varanasi
Kashi Mangali	YVMV & OLCV resistant; suitable for summer; yield: 13-15 t/ha	ICAR-IIVR, Varanasi
Kashi Satdhari	YVMV resistant; medium tall; yield: 11-14 t/ha	ICAR-IIVR, Varanasi
Shitla Jyoti	YVMV & OLCV resistant; medium tall; yield: 18-20 t/ha	ICAR-IIVR, Varanasi
Shitla Uphar	YVMV & OLCV resistant; medium tall; yield: 15-17 t/ha	ICAR-IIVR, Varanasi
Punjab Padmini	YVMV resistant; tall plants; yield: 10-12.5 t/ha	PAU, Ludhiana
Punjab – 7	Medium tall; green, 5-ridged fruits; yield: ~10 t/ha	PAU, Ludhiana
Punjab - 8	YVMV resistant; medium long, tender fruits; yield: ~10 t/ha	PAU, Ludhiana
Hisar Unnat (HRB-55)	YVMV resistant; medium tall; yield: 12-13 t/ha	HAU, Hisar
Varsha Uphar	YVMV resistant; medium tall; fruits 18-20cm; yield: 10 t/ha	HAU, Hisar

CO-1	Tolerant to high temperatures; suitable for multiple seasons; yield: 12-15 t/ha	TNAU, Coimbatore
CO-2	Traditional selection; suitable for various seasons	TNAU, Coimbatore
CO-3	Moderate YVMV resistance; crop duration: 100-110 days; yield: 16-18 t/ha	TNAU, Coimbatore
MDU-1	Induced mutant from Pusa Sawani; early flowering; fruits - 20cm	TNAU, Madurai
Gujrat Bhendi - 1	Erect plants; tender green fruits; yield: 7 t/ha	GAU, Ahemdabad
White Velvet	Popular local variety in Karnataka	Local Selection
Pusa Makhmali	Early; smooth, straight, light green fruits; yield: 10 t/ha	IARI, New Delhi

Hybrids

Hybrids	Key Traits	Developed by
Kashi Shristi (VROH-12)	High yield; adaptability; F1 Hybrid	ICAR- IIVR, Varanasi
Kashi Bhairav	YVMV & OLCV resistant; dark green fruits; yield: 20-22 t/ha	ICAR- IIVR, Varanasi
Arka Nikitha	Early flowering; dark green, tender fruits; yield: 21-24 t/ha	IIHR, Bengaluru
Arka Abhay	YVMV resistant; tall plants; yield: 18 t/ha	IIHR, Bengaluru
OH-102	Tolerant to YVMV	Private Company (likely from a hybrid company)
OH-389	Wide adaptability	Private Company
OH-517	Excellent virus resistance	Private Company

OH-597	Moderate YVMV tolerant	Private Sector
OH-940	Field resistance to YVMV	Private Sector
OH-2324	Vigorous, cut leaves	Private Sector
Advanta F1 Hybrid Navya	High-yielding	Advanta Seeds
Advanta Raadhika F1	Productive hybrid	Advanta Seeds
Iris Hybrid Okra	Widely grown	Iris Seeds
Gentex LXQ-1033	High yield potential	Gentex Seeds
Shakti Vardhak (Pragya, No. 1001)	Known hybrid lines	Shakti Vardhak Seeds Pvt. Ltd
Singham, Shivansh, Sarvottam	High adaptability and resistance	Various Private Companies
Selvam, Samrat, Sirmour, Shikhar, Shakti	Traits vary	Private Sector / SAU
EMS-8, MDU-1, Prabhani Tillu, CO-2, CO-3	Mutants	Traditional mutant selections

Field Management Practices for Okra Cultivation

Land Preparation

Proper land preparation is essential to create suitable conditions for okra growth and development. It involves plowing the field 2–3 times to a depth of 20–25 cm, followed by breaking clods, removing stubbles and weeds, and refining the soil for optimal plant establishment (Kumar et al., 2019). Incorporating well-rotted farmyard manure @ 20-25 t ha⁻¹, half dose of nitrogen and full dose of phosphorus and potash is applied into the soil at least one week before sowing enhances soil fertility, improves plant growth, and positively impacts yield and quality, ultimately leading to a higher benefit-cost ratio. The final step in land preparation

includes leveling the field and dividing it into small plots, which facilitates better crop management and simplifies maintenance (Kumar et al., 2010).

Seed Sowing and Germination

In the North Indian plains, okra is typically sown twice a year: the spring/summer crop is planted from late february to early march, while rainy season crop is sown in june-july. In the northern hills, sowing occurs between April and June, whereas in South India, okra can be cultivated year-round due to mild winters. Seeds are usually sown directly into the soil, with line sowing being favored over broadcasting to ensure a higher seed rate and facilitate easier cultural management.

The selection of improved okra varieties and knowledge of appropriate sowing timing are crucial for successful okra cultivation, as they ensure favorable environmental conditions throughout all growth stages, leading to extended growth duration and enhanced early vegetative development (Bake et al., 2017a). Delayed sowing exposes okra crops to increased risks of pest and disease infestation (Reddy & Reddi, 2014). Okra seeds exhibit dormancy due to their hard seed coat, primarily caused by the chalazal plug, a condition known as delayed permeability (Kumar et al., 2019). To improve germination, seeds should be soaked in water for 6–12 hours before sowing. While nursery preparation is recommended for better establishment, direct sowing is also possible, though it often results in poor germination. Additionally, treating seeds with Bavistin at 0.2% (or a regionally recommended pesticide) during soaking helps protect seedlings from soil-borne diseases in the early stages (Kumar et al., 2019).

Seed Rate and Spacing

The seed rate for cultivating okra usually falls between 3.5 and 10 kg per hectare, depending on the season and the target spacing. For summer crops, a lower seed rate of 3.5 to 5.5 kg per hectare is typically needed, while rainy season crops require a higher rate of 8 to 10 kg per hectare. Okra spacing varies based on variety and climate but typically ranges from 15–24 inches between plants and 28–38 inches between rows. The recommended row spacing is at least 45 cm (1'5") with a 60 cm (1'11") row gap, while plant-to-plant spacing should be 15–20 cm. Seeds are sown 3–4 inches apart in the row and later thinned to 12–15 inches for dwarf varieties and 18–24 inches for standard to large types (Reddy *et al.*, 2017). Depending on the variety, the ideal plant density ranges from 7,000 to 15,000 plants per acre, ensuring optimal growth, nutrient utilization, and yield potential. Maintaining appropriate spacing helps reduce competition for

nutrients, minimizes the risk of pest and disease infestation, and improves overall crop management (Gbaraneh *et al.*, 2018).

Seed Treatment

To enhance germination efficiency and ensure effective prophylactic protection against biotic stresses in okra (*Abelmoschus esculentus* L.), a series of pre-sowing seed treatments can be adopted.

1. Hydration Treatment (Soaking):

Okra seeds possess a hard and impermeable seed coat, which can hinder rapid water uptake and uniform germination. To overcome this, seeds should be pre-soaked in distilled water for 24 hours. This imbibition process softens the seed coat, accelerates metabolic activity, and facilitates uniform germination.

2. Chemical Seed Treatment (Fungicidal):

Carbendazim (systemic fungicide): Post-soaking, seeds may be treated with a 0.2% aqueous solution of Carbendazim (2 g/L of water) for 6 hours to suppress soil-borne pathogens such as *Fusarium* spp. and *Rhizoctonia solani*. Seeds should then be air-dried under shade to prevent photodegradation of the chemical.

Bavistin (Carbendazim formulation): An alternative is Bavistin at 0.2% concentration, which offers broad-spectrum fungicidal action.

Biological Seed Treatment (Biocontrol Agents):

Trichoderma viride (4 g/kg seed) or *Pseudomonas fluorescens* (10 g/kg seed) can be used to biologically suppress pathogenic fungi via competitive inhibition, mycoparasitism, and induced systemic resistance (ISR).

Azospirillum spp. (400 g per seed lot), when applied with a sticking agent like starch, enhances biological nitrogen fixation and promotes root development through the production of phytohormones like IAA (Indole-3-acetic acid).

Insecticidal Seed Treatment (Sucking Pests Management):

For the management of early-season sucking pests (e.g., aphids, jassids, whiteflies), seeds can be treated with neonicotinoids:

Imidacloprid: 10 g of 70% WS or 9 ml of 600 FS formulation per kg of seed.

Thiamethoxam: 4.5 g of 70% WS or 9 ml of 35% FS per kg seed. These systemic insecticides provide extended protection during the seedling stage.

3. Additional Germination-Enhancing Techniques:

Seed Priming:

Priming involves controlled hydration to activate metabolic processes without initiating radicle emergence. Techniques such as osmopriming or hydropriming significantly improve seed vigor index, synchrony of germination, and seedling biomass.

Thermal Treatment (Hot Water Soaking):

Seeds may be soaked in hot water at 80°C for 10 minutes—a method particularly useful for wild okra species. This process assists in breaking physical dormancy and enhances germination percentage.

Dormancy Alleviation Treatments:

In seeds exhibiting physiological dormancy, stratification through cold treatment (3°C for 7 days) or exogenous application of gibberellic acid (GA₃) can be employed to stimulate germination by activating dormant embryo tissues.

Nutrient Management

The fertilizer requirement for okra depends on soil fertility and the quantity of organic manure applied. Generally, 20–25 t/ha of FYM is incorporated during land preparation. For optimum yield in open-pollinated varieties, a dose of 100 kg N, 60 kg P₂O₅, and 50 kg K₂O/ha is recommended. Apply half of the nitrogen and the full dose of phosphorus and potassium as basal at planting. The remaining nitrogen is applied 30 days after sowing, followed by earthing up. Fertilizers are applied by making a narrow furrow along one side of each sowing ridge. Suitable nitrogen sources include urea, calcium ammonium nitrate (CAN), and ammonium sulphate. For hybrid okra, the recommended dose is 150 kg N, 112 kg P₂O₅, and 75 kg K₂O/ha. Apply 30% N and 50% of P & K as basal, followed by 40% N, 50% P, and 25% K at 4 weeks after sowing, and the remaining 30% N and 25% K at 7 weeks after sowing as second top dressing (Adekiya *et al.*, 2020).

Irrigation and Water Management

Maintaining consistent soil moisture is crucial, particularly during flowering and fruiting stages. Irrigation should be done every 3–4 days during hot weather using efficient methods like furrow or drip irrigation, with drip being more water-conserving and precise. Okra requires about 1.5 inches of water per week in summer, which reduces to 0.75 inches in cooler conditions. Soil type should be considered, as water-holding capacity varies. Avoiding drought stress is essential

to prevent yield loss and poor fruit quality. Practices like mulching help retain moisture and suppress weeds, while nutrification—applying nutrients through irrigation—enhances nutrient uptake and productivity. Precision irrigation further improves water efficiency and pod uniformity. Ensure the use of non-saline, good-quality water for irrigation. Additionally, hardening seedlings by gradually reducing water 1–2 weeks before transplanting helps acclimate them to field conditions.

Physiological Disorder

Okra requires a balanced supply of macronutrients and micronutrients for optimal growth, yield, and resistance to stress. Nitrogen deficiency causes yellowing of older leaves and stunted growth, which can be managed with urea or ammonium sulfate. Phosphorus deficiency leads to slow growth and dark green or purplish leaves, controlled by superphosphate application. Potassium deficiency results in weak stems and poor fruit quality, addressed with muriate of potash. Calcium deficiency causes deformed leaves and brittle plants, managed through gypsum or calcium nitrate, while magnesium deficiency leads to interveinal chlorosis, corrected with magnesium sulfate. Sulfur deficiency causes uniform yellowing, rectified with gypsum or ammonium sulfate. Among micronutrients, iron deficiency results in chlorosis in young leaves, corrected by ferrous sulfate, while zinc deficiency leads to stunted growth and small leaves, managed with zinc sulfate (Rao *et al.*, 2019). Manganese deficiency causes pale green leaves and poor fruit development, addressed with manganese sulfate. Boron deficiency results in brittle leaves and poor fruit quality, managed with boric acid. Copper deficiency leads to wilting and twisted leaves, corrected with copper sulfate, whereas molybdenum deficiency affects nitrogen metabolism, controlled with sodium or ammonium molybdate. Regular soil testing, balanced fertilization, organic amendments, and timely foliar sprays ensure proper nutrient availability and enhance okra productivity (Gemedie *et al.*, 2017).

Insec pest and disease management

Okra is vulnerable to a wide array of insect pests and diseases, which can affect the crop at various growth stages. For instance, crickets may pose a threat during the germination and seedling phase, while pests such as thrips and whiteflies, along with other phloem feeders, are commonly encountered during the vegetative stage. The occurrence of these insect pests and diseases follows a similar pattern across different growing regions. The Yellow Vein Mosaic

Virus (YVMV) is a challenge that okra growers around the world consistently encounter. So insect pests and diseases are described below.

- **Shoot and Fruit Borer (*Earias vittella*, *Earias insulana*)** – Boreholes in shoots and fruits, fruit deformation.

Management: Use resistant varieties, handpick and destroy infested parts, apply neem-based insecticides, use pheromone traps, and spray spinosad (0.5 ml/l) or emamectin benzoate (0.4 g/l).

- **Jassids (*Amrasca biguttula biguttula*)** – Yellowing, curling, and hopper burn on leaves.

Management: Grow resistant varieties, spray neem oil (5 ml/l), and use imidacloprid (0.3 ml/l) or thiamethoxam (0.25 g/l).

- **Aphids (*Aphis gossypii*)** – Cluster on tender shoots, honeydew secretion leading to sooty mold. **Management:** Encourage natural predators, spray neem oil (5 ml/l), and apply dimethoate (1 ml/l).

- **Whitefly (*Bemisia tabaci*)** – Yellowing and curling of leaves, vector of YVMV. **Management:** Use yellow sticky traps, spray neem oil (5 ml/l), and apply thiamethoxam (0.25 g/l) or acetamiprid (0.3 g/l).

- **Red Spider Mite (*Tetranychus urticae*)** – Webbing on leaves, speckled appearance, leaf discoloration.

Management: Spray neem oil (5 ml/l) or sulfur dust (3 g/l), use spiromesifen (1 ml/l) (Kedar et al., 2014).

Diseases

- **Yellow Vein Mosaic Virus (YVMV)** – Yellow network on veins, stunted growth. **Management:** Grow resistant varieties (Arka Anamika, Pusa Sawani), control whiteflies with imidacloprid (0.3 ml/l), and rogue out infected plants.

- **Powdery Mildew (*Erysiphe cichoracearum*, *Oidium abelmoschi*)** – White powdery patches on leaves.

Management: Apply sulfur dust (3 g/l), wettable sulfur (2 g/l), or hexaconazole (1 ml/l).

- **Cercospora Leaf Spot (*Cercospora abelmoschi*, *C. malayensis*)** – Brown circular spots with yellow halos.

Management: Remove infected leaves, apply mancozeb (2 g/l) or chlorothalonil (2 g/l).

- **Fusarium Wilt (*Fusarium oxysporum f. sp. vasinfectum*)** – Yellowing, wilting, root decay. Management: Use disease-free seeds, treat with Trichoderma (5 g/kg seed), and apply carbendazim (1 g/l) as soil drench.
- **Root Knot Nematode (*Meloidogyne spp.*)** – Galls on roots, stunted growth.
Management: Crop rotation, apply neem cake (250 kg/ha), use *Paecilomyces lilacinus*.

Integrated Pest and Disease Management (IPM)

Use resistant varieties, practice crop rotation, apply neem-based products, use traps for insect monitoring, and adopt biopesticides and judicious pesticide application (Sastry et al., 1974).

Harvesting and Yield of Seeds

Okra seed harvesting requires allowing the pods to mature fully on the plant until they become dry, brown, and brittle—usually occurring in warm and dry weather, which favors proper seed development and drying. Hand harvesting is commonly practiced in India, where mature pods are plucked and further dried under shade to avoid direct sun damage. Once sufficiently dry, seeds are extracted manually or using simple mechanical methods. Poor-quality seeds—dark, shriveled, or damaged—should be discarded. Seeds must be dried to below 8% moisture to prevent fungal infections during storage. Properly dried seeds should be stored in airtight containers in a cool, dry place to maintain viability for the next season. In India, seed yield largely depends on the variety and regional conditions. Under favorable agro-climatic zones, seed yields can reach around 800–1000 kg/ha, though in rainfed or suboptimal areas, yields may drop below 500 kg/ha due to moisture stress or pest pressure during pod development.

Post-Harvest Management

Proper post-harvest handling of okra is essential to preserve quality, reduce spoilage, and enhance market value, especially in warm and humid Indian conditions. **Harvesting** should be done when pods are tender and before they turn fibrous. Gentle handling is necessary to prevent mechanical damage, which can accelerate deterioration. **Cleaning, sorting, and grading** help remove debris and ensure uniformity based on size and quality standards, improving market appeal.

Packaging for local markets often involves using baskets or covering pods with gunny bags, while for export, ventilated cartons of 2.5–5 kg capacity are preferred to maintain freshness.

Transportation and storage must be rapid and preferably in refrigerated conditions to avoid

post-harvest losses. Storage at 8–10°C and 90–95% relative humidity can significantly extend shelf life. A continuous **cool chain** from field to consumer is critical for maintaining export-grade quality.

Post-harvest treatments such as pre-cooling, modified atmosphere packaging (MAP), and edible coatings help extend shelf life by reducing respiration and microbial growth. Applications of calcium chloride and sanitizing agents improve firmness and hygiene. For small farmers, **evaporative cooling** provides a cost-effective short-term storage option in rural areas.

Value addition through dehydration, pickling, or powder production increases shelf life and economic returns. A holistic approach covering the **entire value chain**—from harvesting to storage and processing—is essential for sustainable and profitable okra cultivation in India.

Conclusion

Okra, a tropical and subtropical crop, is drought-resistant and thrives under dry conditions. However, for optimal growth, the soil should be well-prepared, adequately moistened, and enriched with organic matter before sowing. The crop is highly sensitive to extremely low temperatures and frost, making timely sowing at the beginning of the rainy season crucial to avoid exposure to pests and diseases. Proper spacing is essential, with closer spacing recommended in summer and wider spacing during the rainy season to achieve better yields. A balanced nutrient management approach, combining organic and inorganic fertilizers, is necessary for healthy growth and high productivity. Okra typically starts yielding within six weeks of planting and requires continuous harvesting. However, its productivity is significantly affected by pests, diseases, high moisture content, salinity, and yellow vein mosaic virus, which can reduce yields by up to 94% depending on the timing of infestation. Limited success has been achieved in controlling pests using neem oil and chemical treatments like Imidacloprid, though excessive chemical use may lead to pesticide resistance over time. Despite these challenges, okra is a nutrient-rich vegetable, providing essential vitamins such as C and B9, fiber, and antioxidants. It serves as an excellent supplement to diets, particularly in developing nations where cereal-based diets often lack essential nutrients. Additionally, okra offers significant health benefits, including antioxidant properties, and therapeutic effects against hyperlipidemia, diabetes, ulcers, microbial infections, and neurodegenerative diseases. Its low-calorie, fat-free nature further enhances its value as a highly nutritious and beneficial crop.

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THE SCIENCE BEHIND MODERN AGRICULTURAL CONTROL SYSTEMS IN PLANT GROWTH

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Abstract

The control of plant growth represents one of agriculture's most powerful tools for enhancing crop productivity and sustainability. This article explores the biological mechanisms behind plant development and the emerging science of growth controllability. By understanding how genetic programming interacts with environmental factors, modern agricultural systems can guide plant development toward desired outcomes while respecting natural biological processes. Advances in technology now allow precise manipulation of growth conditions, offering promising approaches for addressing challenges in food security and environmental sustainability.

Introduction

When a tiny seed transforms into a towering corn stalk or a fruit-laden apple tree, it's following an intricate growth program that farmers have worked with for millennia. Today, scientists are decoding this program with unprecedented precision, revealing the delicate interplay between genetics, environment, and plant physiology that governs growth.

Plants are nature's original smart systems. They constantly monitor their surroundings and adjust their growth accordingly turning toward light, extending roots toward water, and timing their flowering based on day length. This adaptability has helped plants thrive in diverse environments across our planet. However, in agriculture, we often want plants to grow in specific ways: compact lettuce for efficient harvesting, tomatoes that ripen uniformly, or wheat that stands upright even in strong winds. The emerging science of plant growth controllability aims to achieve these goals by working with rather than against plants' natural growth

mechanisms. Unlike animals that grow mainly through cell division, plants employ a fascinating two-step process. First, new cells form in special regions called meristems, found at the tips of shoots and roots. Then, these cells undergo dramatic expansion, sometimes increasing their volume up to 100 times by taking in water.

This growth is orchestrated through several interconnected systems:

- Primary growth extends the plant upward and downward through the shoot and root tips
- Secondary growth increases the diameter of stems and roots, creating woody tissue in trees and shrubs
- Photomorphogenesis allows plants to develop differently based on light conditions
- Tropisms direct growth toward beneficial resources like light, water, and support structures

Behind these visible changes lies complex plant physiology. Photosynthesis captures energy from sunlight, respiration releases this energy for growth, nutrient uptake provides building materials, and water relations drive cell expansion. Tying everything together is a sophisticated hormone signaling network that coordinates growth responses.

Plant hormones are like the plant's internal messaging system. They translate environmental information into growth decisions. Understanding these hormones has revolutionized how we cultivate everything from greenhouse tomatoes to ornamentals."

Key Factors Influencing Plant Growth

Modern research has classified the factors affecting plant growth into three major categories:

Environmental Factors

- Light affects everything from germination timing to flowering, with different wavelengths triggering specific responses
- Temperature determines enzyme activity rates and developmental timing
- Water availability influences cell expansion and nutrient transport
- Nutrient status provides the building blocks for new tissues
- Carbon dioxide concentration affects photosynthetic efficiency

Genetic Factors

Each plant species carries genetic instructions that determine its growth potential and how it responds to environmental conditions. These genetic differences explain why corn grows tall with a single stem while tomatoes bush outward with many branches.

Biotic Factors

In general, plants do not grow in isolation. They interact with various biotic factors for their growth.

- Beneficial microorganisms like nitrogen-fixing bacteria
- Competing plants that may shade them or compete for resources
- Herbivores that consume plant tissues
- Pollinators essential for reproductive success

Controllability

Modern agriculture increasingly relies on precisely controlling plant growth—whether in high-tech vertical farms or traditional field settings with improved management practices.

The concept of controllability examines how effectively we can direct plant growth toward desired outcomes. Complete control remains theoretical due to the complexity of biological systems, but the modern research has made remarkable progress in guiding specific aspects of growth. Today's farmers and researchers leverage both external and internal factors to influence how plants develop:

External Control Strategies

- Light management with LED technology delivers specific wavelengths to trigger desired responses—blue light promotes compact growth, red light stimulates flowering, and far-red light modifies plant architecture
- Temperature modulation influences everything from germination to flowering time
- Precision irrigation delivers water exactly when and where plants need it
- Atmospheric management in greenhouse environments optimizes CO₂ levels and humidity

Internal Control Approaches

- Plant hormone applications supplement natural signals to promote rooting, control height, or coordinate ripening
- Genetic improvements through breeding and biotechnology enhance growth characteristics
- Microbiome management harnesses beneficial soil organisms

The implementation of plant growth control strategies has yielded significant benefits across various agricultural systems:



Productivity Improvements

Controlled environment agriculture consistently demonstrates yield increases of 20-40% compared to conventional methods, while using significantly less land and water. By precisely managing growth conditions, farmers can:

- Accelerate crop cycles, enabling more harvests per year
- Reduce losses from environmental stresses
- Optimize resource allocation within plants (directing energy to harvestable portions)
- Produce crops with consistent quality and appearance

Resource Efficiency

Modern growth control approaches have dramatically improved resource efficiency:

- Water use efficiency has increased by up to 90% in advanced hydroponic systems
- Nutrient runoff has been reduced by 70-80% in precision fertigation systems
- Energy efficiency continues to improve through targeted application of resources

Quality Enhancements

Beyond quantity, controllability techniques have improved crop quality metrics:

- Nutritional content increases of 10-30% for selected compounds
- Extended shelf life through timed ripening
- Improved flavor profiles through stress management
- Reduced pesticide applications by creating unfavorable conditions for pests

Benefits of Control Strategies in Controlled Environment Agriculture

Metric	Parameter	Quantifiable Outcomes	Methodological Context
Biomass Production	Crop Yield	20-40% increase in harvestable biomass per unit area	Compared to conventional field agriculture under standardized nutrient inputs
	Production Cycle	30-45% reduction in time-to-harvest	Measured across multiple crop species with optimized

			environmental parameters
	Stress Response Mitigation	15-25% reduction in yield variability coefficient	Based on controlled stress experiments with uniform genotypes
	Photo assimilate Partitioning	10-35% increase in harvest index	Quantified through Carbon-14 labeling studies of carbon allocation
Resource Use Efficiency	Water Use Efficiency (WUE)	80-95% reduction in water consumption per kg yield	Measured in recirculating hydroponic systems compared to conventional irrigation
	Nitrogen Use Efficiency (NUE)	65-80% reduction in nitrogen	Determined through mass-balance analyses in precision fertigation
	Photosynthetic Photon Efficacy	2.0-2.8 $\mu\text{mol CO}_2$ fixed per joule of input	Quantified through integrated Photosynthetic Photon Flux Density (PPFD) and gas exchange measurements
Product Quality Parameters	Phytonutrient Concentration	5-30% increase in target secondary metabolites	Analyzed via High-Performance Liquid Chromatography (HPLC) quantification of specific compounds
	Postharvest Longevity	40-60% extension of marketable shelf	Measured through standardized storage

		life	tests and quality degradation curves
	Organoleptic Properties	Statistically significant improvement in sensory panel scores ($p < 0.05$)	Evaluated through blind comparative studies with trained tasting panels
	Pesticide Application	60-90% reduction in pesticide active ingredient requirements	Documented in integrated pest management protocols using climatic controls

Challenges

Despite significant advances, controlling plant growth remains challenging. Plants respond to their environment in complex, non-linear ways. A change in one factor like temperature can completely alter how plants respond to another factor like fertilizer.

Environmental heterogeneity in field conditions creates additional complexity. While a greenhouse can maintain consistent conditions, open fields experience natural variability in light, temperature, and soil properties—sometimes over very short distances.

Scientists address these challenges through several modeling approaches:

- Empirical models use statistical relationships between inputs and outputs
- Mechanistic models represent the underlying physiological processes
- Machine learning techniques identify complex patterns in growth data

Conclusion

As climate change intensifies and population growth continues, our ability to guide plant growth becomes increasingly important for food security and environmental sustainability.

The most promising approaches combine precision with adaptability. Rather than forcing plants into unnatural patterns, recent research study their intrinsic growth mechanisms while guiding them toward productive outcomes. By deepening our understanding of plant growth and

developing tools to guide it effectively, we're cultivating not just better crops but a more sustainable relationship with the natural systems that feed us all.

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ROLE OF SEAWEED EXTRACT IN VEGETABLE PRODUCTION

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Introduction

Seaweeds are various forms of marine algae that are non-complex, autotrophic organisms and exist chiefly in the oceans. Although the term "seaweed" is colloquially used to refer to any marine plant-like organism, it should be remembered that seaweeds are not plants but are actually a part of the protist group known as algae. Seaweeds are divided into three broad categories according to their pigments and cell structure: red algae (Rhodophyta), brown algae (Phaeophyta), and green algae (Chlorophyta). All of these groups are different from one another and suited to various ecological niches within the marine habitat. Seaweeds are also utilized in the manufacture of various products, such as cosmetics, fertilizers and even certain medical and industrial purposes. The nutritional content of seaweed is significant in that it contains high levels of vitamins, minerals, and other bioactive compounds. Seaweed extract is becoming more widely used in agriculture due to its promise in organic and sustainable agriculture.

Their extracts have been found to have beneficial effects on vegetable yields, nutrient acquisition and environmental stress tolerance. Seaweed extract also defend against pests and diseases and enhance seed germination and root growth. The rationale behind these advantages is enhanced photosynthetic activity, enhanced water and nutrient absorption and the availability of plant hormones. Cultivation of seaweed is picking up pace especially along the coast and in nations such as India. The application of seaweed in the manufacture of commercial products such as alginate and agar only add to its importance. Finally, the application of seaweed extracts as a bio stimulant and bio-fertilizer provides a green and sustainable approach to enhancing

vegetable yields while decreasing dependence on chemical fertilizers.

Role of seaweed in vegetable production

Seaweed can be of great help in vegetable production by its use as a natural fertilizer or soil conditioner. Seaweed has become increasingly popular in agriculture because of its high nutrient content and the beneficial impact it can have on plant growth and soil health.

Some of the important roles of seaweed in vegetable production are as follows:

Nutrient Enrichment

Seaweed extracts contain essential nutrients like nitrogen, phosphorus, potassium, trace elements, and growth-stimulating compounds. Plants can easily take up these nutrients, enhancing good growth, development, and higher yields in vegetable crops.

Soil Conditioning

Seaweed has the ability to improve soil structure and water retention. Seaweed is comprised of natural polymers that contribute to enhancing the texture of the soil, making it more friable and its water-holding capacity higher. This is especially advantageous in sandy soils that have a tendency to drain very fast since seaweed retains water for plant use.

Stress Resistance

Seaweed extracts are rich in chemicals such as cytokinin's, auxins, and betaines that can increase a plant's tolerance to environmental stresses like drought, salinity, and temperature stress. This can lead to improved resilience and productivity in vegetable crops.

Bio stimulant Properties

Seaweed is a bio stimulant that stimulates several physiological processes in plants. It can induce seed germination, root growth, and flowering, resulting in overall improved plant health and productivity.

Disease Resistance

Seaweed extracts have been found to possess disease-suppressive effects in some studies, which could be used to defend vegetable crops against some diseases. Seaweed contains chemicals that can trigger the natural defence of plants, thus making them disease-resistant.

Enhanced Nutrient Absorption

Seaweed extracts are rich in chemicals that facilitate nutrient absorption by plants. This can result in better use of nutrients from the soil and less reliance on artificial fertilizers and reduced environmental footprints.

Environmental Sustainability

The utilization of seaweed in vegetable farming fits into the concept of sustainable agriculture. Seaweed is a renewable resource that may be harvested without environmental damage, and its use can help decrease the dependence on synthetic chemicals in agriculture.

Effect of different bio stimulants on major vegetable crops:

S.no	Crop	Effect reported	Seaweed
1	Tomato	Increased germination rate and seedling vigour	<i>Ascophyllum nodosum</i>
		Increased root and shoot growth	<i>Sargassum spp.</i>
		Increased chlorophyll content	<i>Cystoseira myriophylloides</i>
		Increased flowering	<i>Gelidium serrulatum</i>
		Increased yield	<i>Ulva lactuca</i>
		Improved fruit quality	<i>Laminaria digitate</i>
		Improved resistance to pathogens fusarium wilt, early blight. Increased tolerance to salinity, drought and cold stress.	<i>Focus spiralis</i>
2	Sweet pepper	Increased root and shoot growth	<i>Ascophyllum nodosum</i>
		Increased chlorophyll content	<i>Sargassum spp.</i>
		Increased flowering	<i>Acanthophora spicifera</i>
		Increased yield	
		Improved fruit quality	
		Improved resistance to pathogens early blight, fruit rot. Increased tolerance to salinity and drought stress.	
3	Potato	Improved growth	<i>Ascophyllum nodosum</i>
		Increased yield and tuber quality	<i>Kappaphycus alvarezii</i>
		Increased resistance to drought stress	<i>Gracilaria edulis</i>

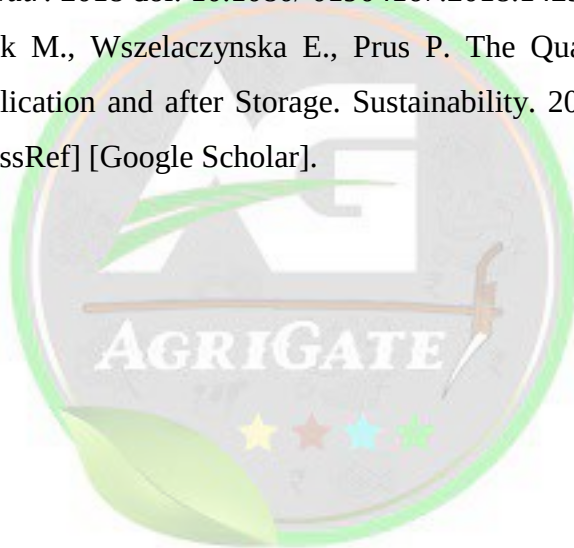
4	Carrot	Increased harvest index	<i>Ascophyllum nodosum</i>
		Improves nutritional content Reduction of fungal disease severity caused by black rot and grey mold	<i>Ecklonia maxima</i>
5	Onion	Increased germination rate and seedling vigour Increased bulb diameter and weight Increased mineral content Increased ascorbic acid Disease reduction caused by powdery mildew	<i>Ascophyllum nodosum</i>
6	Cauliflower	Increase in curd heart size and diameter	<i>Ascophyllum nodosum</i>
7	Cucumber	Increased yield	<i>Ascophyllum nodosum</i>
		Enhances nutritional content in fruit	<i>Macrocystis pyrifera</i>
		Reduces fungal infections like leaf spot, blight, grey mold and powdery mildew.	<i>Ulva armoricana</i>

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TILLING AND ECOTILLING FOR CROP IMPROVEMENT

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Abstract

TILLING (Targeting Induced Local Lesions IN Genomes) and EcoTILLING (Ecotype Targeting Induced Local Lesions IN Genomes) are powerful molecular techniques that enable the identification of genetic variations in plants. tilling focuses on induced mutations to study gene function and develop improved crop varieties, while eco-tilling leverages natural genetic diversity within populations. These methods are highly valuable in functional genomics, genetic diversity studies, and plant breeding programs. This document explores the principles, methodologies, applications, and future prospects of tilling and eco-tilling, emphasizing their role in addressing global agricultural challenges.

Key words: Tilling, Eco-tilling, Molecular Techniques

Introduction

The ever-growing global population and the challenges posed by climate change have intensified the demand for sustainable agricultural practices and high-yielding crop varieties. Traditional plant breeding methods, though effective, are often time-consuming and limited in

scope. Modern molecular techniques like tilling and ecotilling have revolutionized plant breeding by enabling the rapid identification of genetic variations that can be exploited for crop improvement. These techniques offer non-transgenic alternatives to genetic modification, making them suitable for regions with stringent regulations against genetically modified organisms (GMOs). By targeting specific genes or leveraging natural genetic diversity, tilling and ecotilling contribute significantly to functional genomics, trait improvement, and biodiversity conservation.

This document delves into the methodologies, applications, and comparative analysis of tilling and ecotilling, shedding light on their importance in modern agriculture. Additionally, it discusses future prospects and their potential to address global food security challenges.

TILLING

Definition and Principles

TILLING, or Targeting Induced Local Lesions IN Genomes, is a reverse genetics approach that facilitates the discovery of mutations in specific genes of interest. This technique involves the induction of random mutations in the genome using chemical mutagens such as ethyl methanesulfonate (EMS). The mutated population is then screened to identify alleles that exhibit changes in the gene of interest. By identifying and utilizing these mutations, researchers can study gene functions and develop improved crop varieties. (Till *et al.*, 2007, Bhattacharya *et al.*, 2023)

Methodology

1. Mutagenesis

- Seeds or plant tissues are exposed to chemical mutagens like EMS, which introduces point mutations in the genome.
- Mutagenized populations are grown and maintained for further analysis.

2. DNA Extraction and PCR Amplification

- DNA is extracted from individual plants in the mutagenized population.
- The gene of interest is amplified using specific primers through polymerase chain reaction (PCR).

3. Mutation Detection Techniques

- Mismatch-specific endonucleases are employed to detect single nucleotide polymorphisms (SNPs) and small insertions or deletions (indels).

- Techniques like capillary electrophoresis or high-throughput sequencing are used to analyze the results (Malik, 2023).

Applications

- **Functional Genomics:** TILLING enables researchers to study gene function by analyzing the phenotypic effects of specific mutations.
- **Crop Improvement:** Mutant alleles identified through TILLING can be used to develop varieties with desirable traits such as improved yield, disease resistance, and stress tolerance.
- **Identification of Novel Alleles:** This technique facilitates the discovery of new genetic variations that may not be present in natural populations.

EcoTILLING

Definition and Principles

EcoTILLING, or Ecotype Targeting Induced Local Lesions IN Genomes, is a variation of TILLING that focuses on identifying natural genetic polymorphisms within populations. Unlike tilling, ecotilling does not involve induced mutations but rather examines the natural allelic diversity present in ecotypes or cultivars. This technique is widely used for genetic diversity studies and conservation (Till *et al.*, 2007, Mohapatra *et al.*, 2023)

Methodology

1. Population Selection

- Genetic material is collected from diverse populations, ecotypes, or cultivars of a species.

2. DNA Extraction and PCR Amplification

- DNA is extracted from the selected samples.
- Specific regions of interest are amplified using PCR.

3. Polymorphism Detection Techniques

- Mismatch-specific endonucleases or high-throughput sequencing are used to detect natural polymorphisms such as SNPs and indels (Malik, 2023).

Applications

- **Genetic Diversity Studies:** EcoTILLING helps assess the genetic diversity within and between populations, aiding in conservation efforts.

- **Identification of Natural Alleles:** Useful alleles associated with beneficial traits can be identified for breeding programs.
- **Germplasm Conservation:** EcoTILLING aids in the characterization and preservation of genetic resources for future use.

Comparison Between TILLING and EcoTILLING

Aspect	TILLING	EcoTILLING
Source of Variation	Induced mutations via mutagenesis	Natural genetic variation in populations
Purpose	Reverse genetics and gene function analysis	Population genetics and diversity studies
Material Used	Mutagenized populations	Natural populations/ecotypes

Conclusion

TILLING and EcoTILLING have emerged as transformative tools in plant breeding and genetic research. By enabling the identification of induced and natural genetic variations, these techniques facilitate the development of improved crop varieties without the need for transgenic approaches. Their applications in functional genomics, genetic diversity studies, and sustainable agriculture underscore their significance in addressing food security and environmental challenges. The continued advancement of these methods will further enhance their utility and impact.

Future Prospects

The future of TILLING and EcoTILLING lies in their integration with cutting-edge technologies such as next-generation sequencing (NGS) and CRISPR-Cas9. Automation and high-throughput platforms will streamline the screening process, making these techniques more efficient and accessible. Expanding their application to underutilized and minor crops can diversify the agricultural gene pool, promoting resilience against climate change and biotic stresses. Additionally, collaborative efforts between researchers, breeders, and policymakers will ensure that these techniques contribute meaningfully to global food security and sustainable agricultural practices. By combining innovation with precision, TILLING and EcoTILLING are poised to play a pivotal role in shaping the future of agriculture, addressing the challenges of a growing population, and mitigating the impacts of a changing climate.

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SPIRITUALITY IN AGRICULTURE: A HISTORICAL AND CONTEMPORARY EXPLORATION

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Abstract

This article explores the intricate relationship between spirituality and agriculture, a connection deeply rooted in human history and experiencing a contemporary resurgence. It defines "spirituality in agriculture" as the understanding that food production, consumption, and the essential spiritual nature of humanity are fundamentally linked. The article examines the historical prevalence of this connection across diverse cultures and religions, highlighting ancient rituals and beliefs that underscored the sacredness of farming. It delves into the perspectives of various religious traditions, including Abrahamic, Eastern, and Indigenous spiritualities, on agriculture and environmental stewardship. Furthermore, the report analyzes modern examples of spiritually inspired agricultural practices, such as faith-based farming, biodynamic agriculture, and indigenous regenerative techniques, and discusses their potential benefits for sustainability and human well-being. While acknowledging the challenges and criticisms associated with integrating spirituality into modern agriculture, the article concludes by emphasizing the



enduring significance of this relationship for fostering a more holistic, ethical, and sustainable future for food systems and the planet.

Introduction

Agriculture has been a cornerstone of human civilization since its inception, fundamentally shaping societal structures, cultural practices, and belief systems. Throughout history, the cultivation of land and the production of food have been more than mere practical activities; they have been deeply intertwined with spiritual beliefs and practices. As contemporary society grapples with the environmental and social consequences of industrial agriculture, there is a growing interest in reconnecting with more holistic and sustainable approaches to food production. The concept of "spirituality in agriculture" provides a framework for understanding this enduring connection, encompassing a wide range of interpretations that span from specific religious doctrines to broader philosophical perspectives emphasizing interconnectedness and reverence for nature.

Defining Spirituality in Agriculture

At its core, spirituality in agriculture refers to the idea that the processes of food production and consumption are intrinsically linked to the spiritual essence of humanity. The concept of "Agricultural Spiritualism" specifically posits that spirituality is an inherent aspect of human consciousness, potentially arising from it, and accessible to all through dedicated cultivation, drawing parallels between nurturing crops and nurturing the spirit. Understanding this spiritual link addresses fundamental ethical considerations within agriculture, serving as a means of communication and fostering a relationship between the spirit of the land and the spirit of the people through everyday farming practices. Beyond these specific definitions, spirituality in agriculture can encompass broader notions such as a deep sense of interconnectedness with all living things, a profound reverence for the natural world, the practice of mindfulness in farming activities, and a recognition of a purpose that transcends mere economic gain. This perspective stands in contrast to purely mechanistic or economic views of agriculture that often prioritize efficiency and profit over ecological and ethical considerations.

Historical and Cultural Roots of Spirituality in Agriculture

The intertwining of agriculture and spirituality has deep historical roots, evident in ancient societies across the globe. Ancient cultures commonly engaged in agricultural rituals, ceremonies, and offerings as a way to invoke divine blessings for fertile land, abundant harvests,

and protection from natural calamities. These practices often involved specific deities and spirits associated with agriculture, reflecting a belief in the sacred nature of the life-sustaining act of farming. Harvest celebrations, marking the culmination of the agricultural cycle, were frequently imbued with deep spiritual significance, expressing gratitude for the bounty of the earth and reinforcing community bonds. Examples of these ancient traditions abound across different civilizations. In Mesopotamia, the Akitu festival celebrated the end of the agricultural year with offerings to gods like Marduk and Ishtar. Ancient Egyptians revered the annual flooding of the Nile, which enriched their soil, with offerings to Hapi, the god of inundation. Greek and Roman traditions associated harvest time with Demeter, the goddess of agriculture, and celebrated the bounty with festivals like Thesmophoria and Saturnalia. Native American tribes, such as the Cherokee, held the Green Corn Ceremony as a time for renewal and gratitude for the ripening maize. Similarly, ancient agricultural societies often had rituals tied to planting seasons and the overall cycle of life, underscoring the spiritual dimension of cultivation. However, with the advent of the scientific revolution and the rise of industrial paradigms, a gradual shift occurred, leading to a more mechanistic view of agriculture that often marginalized its spiritual dimensions.

Table 1: Examples of Ancient Agricultural Rituals and Associated Spiritual Beliefs

Culture	Specific Ritual/Festival	Associated Spiritual Belief/Deity
Mesopotamia	Akitu Festival	Marduk and Ishtar
Ancient Egypt	Nile Flooding Offerings	Hapi
Greece	Thesmophoria	Demeter
Rome	Saturnalia	Saturn
Native American (Cherokee)	Green Corn Ceremony	Maize Spirit
China	Mid-Autumn Festival	Moon
India	Pongal	Sun God

Perspectives on Agriculture and Spirituality

Diverse religious traditions offer unique perspectives on the relationship between agriculture and spirituality, often emphasizing humanity's role as stewards of the Earth and the sacredness of food.



Abrahamic Religions (Judaism, Christianity, Islam)

These faiths share a concept of stewardship, highlighting humanity's responsibility to care for the Earth and its resources as a divine mandate. Judaism, for instance, incorporates agricultural practices into religious observance, exemplified by the concept of Shmita, the Sabbatical year requiring the land to rest every seven years. Christian perspectives often view farming as a noble calling, with biblical teachings emphasizing the creation of a magnificent garden by God, which serves as a model for human cultivation. The Islamic concept of "tayyib" emphasizes purity and wholesomeness in food production, extending to ethical and environmentally sound practices. Food holds a sacred place in these religions, evident in rituals like the Christian Eucharist, Jewish dietary laws (Kashrut), and Islamic Halal practices. Faith-based organizations often initiate agricultural projects grounded in these spiritual principles, such as the Jesuit-run agricultural centers that teach organic farming as a spiritual encounter and the "Farming God's Way" initiative, which integrates biblical teachings with sustainable agricultural practices in Africa.

Eastern Religions (Hinduism, Buddhism, Daoism)

These traditions often emphasize the interconnectedness of all life, the principle of non-violence (ahimsa), and a deep reverence for all living beings, which have significant implications for agricultural practices. Hinduism promotes vegetarianism based on the principle of ahimsa, advocating for food choices that minimize harm to other life forms. Buddhism recommends mindful eating and, in some interpretations, the avoidance of meat, aligning with a philosophy of compassion and non-harming. Spiritually inspired agricultural programs in these traditions include Thailand's "Moral Rice" initiative, which connects Buddhist farmers with spirituality through organic farming to purify both their spirits and the rice. The Brahma Kumaris Environment Initiative promotes "sustainable yogic farming," combining organic farming with meditation and a vegetarian lifestyle. Daoism emphasizes living in harmony with nature and respecting natural cycles, influencing food ethics towards organically grown produce without artificial chemicals.

Indigenous Spiritual Traditions

Indigenous cultures worldwide hold a profound spiritual connection to the land, viewing it as a living entity and themselves as its caretakers rather than owners. Their traditional ecological knowledge (TEK), passed down through generations, encompasses sustainable

farming practices developed over millennia, such as intercropping, crop rotation, agroforestry, and water harvesting. The "Three Sisters" planting method, a companion planting technique involving corn, beans, and squash, is a prime example of this, holding deep cultural and spiritual significance for many Indigenous nations in North America. Rituals and ceremonies often play a vital role in their agricultural cycles, expressing gratitude and seeking balance with the natural world.

Modern Examples of Spirituality in Agricultural Practices

In contemporary society, various initiatives demonstrate a renewed interest in integrating spiritual values into agricultural practices, often driven by concerns for sustainability, ethics, and personal well-being.

Table 2: Modern Examples of Spiritually Inspired Agricultural Practices

Practice	Spiritual Inspiration	Key Principles/Practices
Farming God's Way	Christian teachings	Minimal soil disturbance, permanent organic cover, crop rotation, attention to detail, agroforestry.
Biodynamic Agriculture	Anthroposophy	Holistic farm management, viewing the farm as a living organism, use of specific biodynamic preparations.
Zero Budget Natural Farming (ZBNF)	Indian spiritual philosophy	Reliance on natural inputs (cow dung, urine), no external fertilizers or pesticides, emphasis on soil health and natural processes.
Moral Rice Program	Buddhism	Connecting farmers with spirituality through Buddhist practices, organic farming, aiming for spiritually and agriculturally purified rice.
Indigenous-Led Regenerative Agriculture	Indigenous spiritual connection to land	Revitalizing traditional ecological knowledge, focusing on ecological restoration, practices like intercropping, polyculture, and respecting natural cycles.
Jesuit Agricultural Centers	Christian perspective (Jesuit)	Teaching organic farming as a spiritual encounter, connecting with God through agricultural activities, emphasis on ecological awareness and the "cultivation and perfection of human beings".
Mindful and Compassionate	Ayurveda, general spirituality	Sending love and positive energy to plants, practicing mindfulness during farming



Farming		activities, recognizing the sensitivity of plants to their environment and human intentions.
Community Supported Agriculture (CSA)	Varied, often emphasizing connection	Fostering a sense of shared responsibility and appreciation between consumers and farmers, promoting local and sustainable food systems, often with an ethical or spiritual underpinning in the relationship.
Urban Farming and Community Gardens	Varied, often emphasizing connection	Reconnecting with nature in urban environments, fostering community engagement, providing a sense of purpose and well-being through cultivating food, often with a spiritual appreciation for the process of growth and the earth.

Benefits of Integrating Spirituality into Agriculture

Incorporating spiritual values and practices into farming can yield numerous positive outcomes. It can lead to an enhanced sense of mindfulness and awareness, encouraging farmers to be more present and attentive to the nuances of their land and crops. A spiritual perspective often cultivates compassion and respect for all living beings, fostering more ethical treatment of plants, animals, and the environment. These values naturally align with principles of environmental stewardship, promoting sustainable farming practices such as organic and regenerative methods that enhance biodiversity. Engaging with agriculture from a spiritual standpoint can deepen the connection between farmers and the land, fostering a more harmonious and reciprocal relationship with nature. This deeper connection, coupled with a sense of purpose beyond mere profit, can contribute to increased well-being and reduced stress for those involved in farming. Furthermore, spiritually oriented agricultural initiatives often strengthen community bonds through shared values and collaborative practices. Ultimately, by emphasizing harmony with natural processes, spiritual agriculture can contribute to the development of more resilient and sustainable food systems that work in accordance with the natural order.

Challenges and Criticisms of Spiritual Approaches

Despite the potential benefits, integrating spirituality into modern agriculture also presents several challenges and has faced criticism. A fundamental challenge lies in the potential

clash between spiritual perspectives and the dominant scientific and economic paradigms that underpin mainstream agriculture, which often prioritize quantifiable results and profit maximization. In a society often characterized by skepticism towards non-materialistic aspects of life, beliefs and practices associated with spiritual agriculture may be met with doubt or dismissal. Some spiritually inspired methods, such as biodynamic agriculture, have been criticized for lacking rigorous empirical evidence to substantiate their claimed efficacy. There is also a risk of superficial or insincere adoption of spiritual language without a genuine commitment to ethical and sustainable practices, potentially leading to misinterpretation or misuse of the concept. Implementing spiritually focused practices in the context of large-scale industrial agricultural systems can pose significant practical challenges. The subjective nature of spirituality itself makes it difficult to establish universal definitions or measurable outcomes in an agricultural context. Finally, there is a potential for certain spiritual approaches to become overly prescriptive or dogmatic, potentially limiting innovation and the adoption of diverse methods.

Spirituality, Sustainability, and the Future of Agriculture:

Spiritual values hold a crucial role in addressing the pressing challenges facing contemporary agriculture and shaping a more sustainable future for food systems. The inherent respect for nature found in many spiritual traditions can serve as a powerful motivation for adopting environmentally responsible farming practices, which are essential for mitigating climate change, preventing soil erosion, and preserving biodiversity. Furthermore, spiritual principles emphasizing compassion and fairness can drive efforts towards achieving food security and ensuring equitable access to nutritious food for all members of society. A renewed appreciation for the spiritual dimensions of agriculture can contribute to reclaiming the sacredness of food, shifting the focus from mere consumption to a deeper understanding of its life-giving properties and the interconnectedness of all living beings. Embracing spirituality can foster a more holistic approach to agriculture, one that values both scientific knowledge and spiritual wisdom, recognizing the inherent limitations of purely reductionist perspectives. Finally, spiritually grounded agricultural practices can empower farmers and communities by fostering a deeper sense of connection to their work, their land, and each other, moving away from the alienation often associated with industrial agriculture.



Conclusion

Spirituality has played and continues to play a vital role in shaping human interactions with agriculture. From ancient rituals seeking divine favor for harvests to contemporary initiatives promoting sustainable and ethical farming practices, the connection between the spiritual and the agricultural is undeniable. This article has explored the meaning of spirituality in agriculture, its historical and cultural roots, diverse religious and indigenous perspectives, modern manifestations, potential benefits, and associated challenges. The enduring relevance of this relationship lies in its capacity to foster a deeper sense of responsibility towards the Earth, promote more ethical and sustainable food systems, and enhance the well-being of individuals and communities. As we look to the future, a more integrated and spiritually informed approach to agriculture holds significant potential to contribute to a more just, resilient, and thriving world for generations to come.

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HOST DEFENSE PEPTIDES: CHARACTERIZATION AND THEIR IMMUNOMODULATORY AND THERAPEUTIC POTENTIAL AS ANTIMICROBIAL, ANTIVIRAL, AND ANTIPARASITIC ADJUNCTS**Article ID: AG-VO5-I05-24****Marutheeswara Pandiyan M^{*1}**

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Abstract

The rise of resistance to the conventional vaccines and antibiotics among the pathogens has prompted the urgent search for alternatives. Host defense peptides (HDPs), naturally occurring components of innate immunity, offer a promising solution due to their broad-spectrum antimicrobial, antiviral, antiparasitic, and immunomodulatory properties. This review highlights the structural and functional characteristics of HDPs, including their mechanisms of action, selectivity, and minimal tendency to induce resistance. It explores the therapeutic potential of HDPs in combating bacterial, viral, and parasitic infections, alongside the current challenges limiting their clinical implementation. The review also discusses the identification and characterization of HDPs particularly from helminths and other pathogens, their extraction, profiling techniques, and strategies to enhance their therapeutic viability. HDPs represent a compelling frontier in anti-infective drug development, with the potential to reshape future antimicrobial strategies.

Keywords: Host defense peptides, immunomodulation, antimicrobial, antiviral, antiparasitic, innate immunity, therapeutic peptides and peptide characterization.

Introduction

The global spread of infectious diseases pose a threat to human and animal health especially in regions with limited access to healthcare and sanitation. These diseases, caused by a range of pathogens including bacteria, viruses, fungi, and parasites that challenge the immune system's ability to respond quickly and effectively. The host immune systems try to fight the

infection and defend against the pathogen through innate and adaptive immune systems, The former includes physical barriers (like the skin and mucous membranes), cellular components such as **macrophages, neutrophils, and dendritic cells** which work together to recognize and eliminate pathogens quickly, while the latter comprises **T cells** and **B cells** which is slower to respond but provides specificity and memory, allowing fast and robust reaction upon re-exposure to the same pathogen.

Even though our immune system is powerful and efficient, medical interventions are sometimes required to fight against the pathogens especially when the **infectious load is too high**, the **pathogen is particularly aggressive**, or the **immune response is weakened**, such as in infants, the elderly, or immune compromised individuals. In these cases, **antibiotics** play a critical role by directly reducing the bacterial population, preventing complications, and giving the immune system a better chance to recover control. The administration of antibiotics to combat the infection leads to the ever-escalating problem of antibiotic resistance among the pathogens. To tackle this issue it is important to search for alternative strategies to combat infections.

One such alternate for antibiotics are Host Defense Peptides (HDP), a biologically active endogenous peptides. This can be further sub-divided into Antimicrobial peptides (AMPs) and Anticancer peptides (ACPs) [1]. These short (50 amino acids long), positively charged, amphipathic HDPs are a better alternative due to their **broad-spectrum and rapid antimicrobial properties**, as well as a **lower tendency for inducing resistance** [2,3]. These HDPs are ubiquitous in nature and are critical components of the innate immune system. Unlike the traditional antibodies which often target a specific biosynthetic pathway, these HDPs can **physically destabilize microbial membranes**, thus **circumventing classical drug resistance mechanisms** [6]. Hence **ongoing efforts to explore and harness the therapeutic potential of these quintessential peptides** hold significant promise for advancing drug discovery and addressing the growing challenge of antimicrobial resistance.

Exploitation of HDPs Against Infectious Pathogens

Ever since the discovery of HDPs as the natural defense against pathogen infections, it started gaining rapid attention and its therapeutic potential are studied across for a broad spectrum of pathogens. Recent advances in molecular biology, proteomics, and immunological

assays have paved the way for detailed investigation and functional characterization of HDPs in diverse infectious contexts.

HDPs Against Bacterial Infections

In order to understand the selectivity and develop targeted therapy against microbial infections, It is important to understand the distinctions that lies in the fundamental structural differences between microbial and host cell membranes. The architectural variances between Gram-positive and Gram-negative bacteria not only influence their pathogenic mechanisms but also affect their vulnerability to HDPs.

Structural differences in Bacteria : Gram Positive Vs Gram Negative:

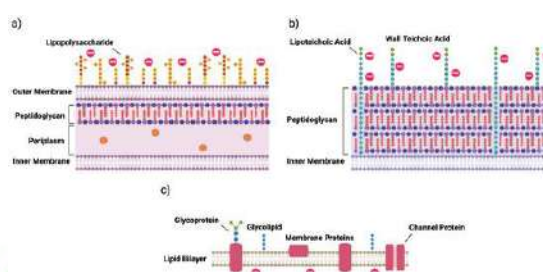


Figure 1: Structures of (a) Gram-negative bacterial cell walls; (b) Gram-positive bacterial cell walls; and (c) mammalian cell membranes. [7]

Though both Gram Negative and Gram Positive bacteria possess a net negative charge, The difference lies in their structure. In Gram-negative bacteria, the outer membrane overlays a thin, rigid peptidoglycan layer composed of alternating N-acetylglucosamine and N-acetylmuramic acid residues. This composite structure contributes to cellular integrity by counteracting the internal osmotic pressure, thereby stabilizing the inner membrane and preventing lysis[8] . The periplasmic space lies sandwiched between these layers, which is a gel-like compartment rich in enzymes essential for cell wall remodeling and the sequestration of potentially harmful molecules such as RNases. These unique architectural features make Gram-negative bacteria more resilient to certain antibiotics but also serve as precise targets for host defense peptides, which are capable of permeabilizing or disrupting these specialized membranes.

In contrast, Gram-positive bacteria lack an outer membrane and are instead encased by a significantly thicker peptidoglycan layer that envelops the inner membrane. This structure is further enriched with anionic glycopolymers, notably teichoic acids, which include wall teichoic acids (WTAs) and lipoteichoic acids depending on their anchoring site [9]. These teichoic acids

gives the negative charge to the bacterial surface, a trait absent in mammalian cell membranes. This electrostatic disparity is a key factor exploited by host defense peptides, enabling them to distinguish bacterial from host cells. Such negatively charged surfaces serve as critical entry points for HDPs, facilitating their initial interaction and subsequent membrane disruption.

Mechanisms of Antibiotic Resistance in Bacteria

There are five major targets that are exploited during the development of antibiotics : the peptidoglycan cell wall, nucleic acid synthesis, metabolic pathways ,protein synthesis and the bacterial cell membrane [10,11]. Many bacteria have quickly developed resistance against the action of these conventional antibiotics either through intrinsic or the structural features inherent to the bacterial species, such as the presence of efflux pumps that actively pump out antibiotics from the cells, absence of antibiotic targets, or variations in membrane architecture (notably between Gram-positive and Gram-negative bacteria, as previously discussed). Alternatively, resistance can be acquired, either through horizontal gene transfer (HGT) from other bacterial strains or via spontaneous mutations in chromosomal DNA [12,13].

Host Defense Peptides:

HDPs are one of the key contributors in the host defense systems. Apart from HDPs activity against a broad-spectrum of bacteria and pathogen [14,15], few HDPs also possess immune-modulatory functions and modulate the host immune systems and have anti-inflammatory functions [16,17]. The pathogens show a slow or no resistance generation against the HDPs compared to the conventional antibiotics which makes HDP a promising alternative for the conventional antibiotics [18,19]. These HDPs have also been found effective against the biofilm-associated bacteria [20,21,22].

Mode of action of HDPs:

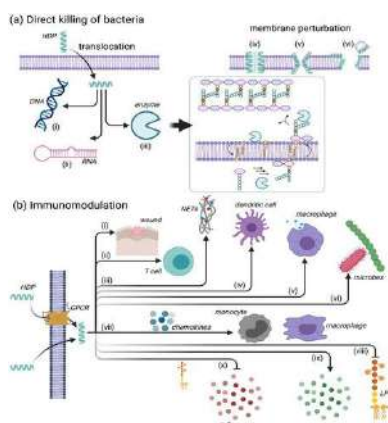


Figure 2. (a) direct bacterial killing and (b) immunomodulation. In (a), HDPs can penetrate bacterial membranes and target intracellular components like (i) DNA, (ii) RNA, or (iii) disrupt biosynthetic pathways by binding to proteins or substrates. In (b), intracellular uptake occurs either through G protein coupled receptors (GPCRs) (yellow) or direct translocation [28].

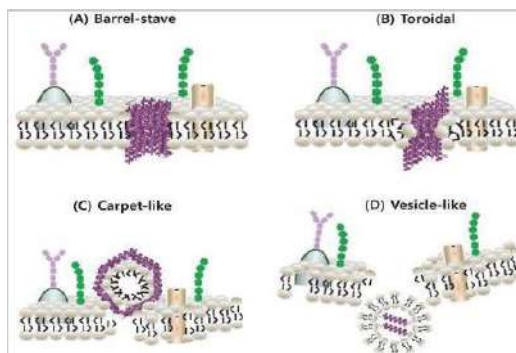


Figure 3 (a) Barrel-Stave Model, (b) Toroidal Model, (c) Carpet Model **and** (D) Vesicle-Like Body Model . In (a) HDPs insert into the membrane like staves of a barrel, forming pores that leak cytoplasmic contents, leading to cell lysis. In (b) HDPs bend the membrane lipids into a continuous pore, disrupting membrane potential and causing cell death. In (c) HDPs spread across the membrane surface like a carpet, destabilizing it and forming micelles that rupture the membrane. In (d) HDPs enter cells via endocytosis (e.g., macropinocytosis), escape endosomes, and target intracellular components.

Many HDPs kill bacteria by targeting their membranes through electrostatic interactions between the peptides' cationic regions and negatively charged components of bacterial surfaces, such as phospholipids, teichoic acids (in Gram-positive bacteria), and LPS (in Gram-negative bacteria) [23]. Mammalian cell membranes, by contrast, are mostly neutral, lending HDPs their selectivity. Interestingly, some cancer cells expose negatively charged lipids, explaining the anticancer activity of certain HDPs [24,25].

In some cases, HDPs also bind to specific membrane receptors (e.g., nisin) [24,26,27]. After binding, HDPs often self-assemble on the membrane, disrupting its structure through pore formation or detergent-like mechanisms [34,36]. This leads to membrane permeabilization, ion leakage, loss of membrane potential, and eventual cell lysis. Some HDPs also cross into the cytoplasm, where they interfere with vital processes like DNA or protein synthesis. The combination of these actions likely contributes to the low resistance seen with HDPs [27,34].

HDPs Against Viral infections

People all over the world, especially children are highly affected by viral infections [30] and the development of effective therapies is slow hence, There is an urgent need for new antiviral treatments, as existing drugs target only a few viruses. Host defense peptides (HDPs), such as defensins and cathelicidins, are natural components of innate immunity with antimicrobial and immunomodulatory functions. Recent studies highlight their broad-spectrum antiviral activity against both enveloped and non-enveloped viruses, including HIV-1, influenza, RSV, and HSV. This review explores the antiviral properties of HDPs and their potential as novel therapeutic agents.

The HDPs are conserved across plants, insects, birds, reptiles, mammals and fungi due to their direct microbicidal and pleiotropic immunomodulatory properties [31,32,33]. In mammals there are 2 major families of HDPs : cathelicidins and defensins.

1. Cathelicidins

Cathelicidins are a unique family of antimicrobial peptides. They share a conserved cathelin domain and a variable C-terminal region that is cleaved to form active peptides [31]. Although multiple cathelicidins are found in other species (e.g. protegrins in pigs), human possess only a single family of cathelicidins. The only cathelicidin in humans is hCAP-18, encoded by the *CAMP* gene. It is activated by the enzyme proteinase 3, producing LL-37—a 4.5 kDa [35,36], positively charged, amphipathic peptide with an α -helical structure. hCAP-18 is mainly stored in neutrophils and can be induced in epithelial cells, macrophages, and other white blood cells. LL-37 is found in various body fluids like airway secretions, blood plasma, urine, breast milk, and sweat. Its production increases during infections, inflammation, wounding, and with exposure to vitamin D or butyrate. Beyond killing microbes, LL-37 influences immune responses by attracting immune cells, regulating cytokines, affecting dendritic cells, promoting wound healing and blood vessel formation, and controlling cell death [38,39,40].

2. Defensins

α -Defensins are small, positively charged peptides with antimicrobial activity. They belong to a larger family (along with β - and θ -defensins) and were first discovered in neutrophil granules, earning the name “natural peptide antibiotics”[41].

In humans, six α -defensins are encoded by five *DEFA* genes [44]. These peptides share a beta-sheet structure stabilized by disulfide bonds and are produced as inactive prepropeptides, then

activated by proteolytic enzymes (e.g., trypsin for HD5/6). HNP1–4 are mainly found in neutrophils and can also be present in NK cells, B cells, macrophages, and dendritic cells[42,43]. Their release is triggered by immune stimuli like chemokines and TLR activation. HD5 and HD6 are produced by Paneth cells [45,46] in the gut and the female genital tract epithelium[47,48,50]. α -Defensins kill a broad range of bacteria by binding to negatively charged cell surfaces and disrupting membranes. Beyond this, they also attract immune cells, regulate inflammation, shape gut microbiota, and can form nanonets to trap pathogens.

2.a) β -Defensins

β -Defensins are antimicrobial peptides found in many animals, including humans (with over 30 types) and mice (over 50 types). They are the only defensins found in birds and are also seen in reptiles and even sea creatures like sea anemones [51]. Like α -defensins, β -defensins have a three-stranded β -sheet structure, but their disulfide bond pattern is different. The best-studied human β -defensins are HBD1, HBD2, and HBD3 [52,53] the **HBD1** is made constantly by epithelial cells and immune cells like monocytes and macrophages. **HBD2 and HBD3** are produced in response to infections, inflammation, or signals from TLRs, NOD proteins, and cytokines.

They can kill pathogens, though their effectiveness varies. For example, HBD1 is weak unless its structure is altered (disulfide bonds reduced). Some mouse models lacking the *Defb1* gene don't show severe effects, likely due to backup from other defensins [54,55].

Besides killing microbes, β -defensins also help the immune system by Attracting memory T cells, Supporting wound healing and Regulating inflammation.

2.b) θ -Defensins

θ -Defensins are unique circular peptides (made of 18 amino acids in a ring structure) [56], found only in some primates like rhesus monkeys (RTD1–3) [57,58]. They are made from two smaller peptides that join together, each providing three cysteines for disulfide bonding.

Humans have θ -defensin-like genes, but they contain a stop codon, so the proteins aren't made naturally. However, scientists have synthetically made these peptides, similar to α -defensins, and is being explored for potential therapeutic use [59].

HDPs Against Parasite infections

Unlike viruses and bacteria, parasitic helminths are **multicellular organisms** that require a distinctly different approach for effective elimination. Combating parasitic infections demands

a **multifaceted strategy** one that not only targets and disrupts the parasite's membrane integrity but also **modulates the host's immune response** to enhance parasite clearance.

HDPs bind to parasite membranes via electrostatic interactions, causing pore formation, lipid bilayer thinning, or complete membrane disintegration. For example the **Human cathelicidin LL-37** disrupts *Plasmodium falciparum* membranes, reducing malaria parasite viability [60].

Some HDPs penetrate parasite cells to inhibit nucleic acid synthesis, protein production, or metabolic pathways. For instance, Human **Histatin-5 (Hst5)** exhibits potent antiparasitic activity against both life stages of *Leishmania* **promastigotes** and **amastigotes**, Hst5 initiates its effect by **accumulating in the mitochondria**, where it causes **bioenergetic collapse** by **inhibiting mitochondrial ATP synthesis**, ultimately leading to parasite death. This is especially significant for *Leishmania*, which relies heavily on mitochondrial ATP production due to its lack of a glycolysis-to-respiration switch. [61].

Helminthic host defense peptides : Parasite-derived molecules with immunomodulatory effects
Parasitic helminths coexist with host microbiota and have evolved host defense peptides (HDPs) to modulate these microbial communities and protect against pathogens. These HDPs typically act through nonspecific membranolytic activity against bacteria, often with minimal toxicity to host cells. Despite a few known examples like cecropin-like peptides and ABFs in nematodes, helminthic HDPs remain largely understudied [60].

Suppression of Pro-Inflammatory Responses:

Helminth HDPs like FhHDM-1 secreted by the trematode, *Fasciola hepatica*, which causes liver fluke diseases in animals and humans mimic human LL-37 to bind bacterial lipopolysaccharides (LPS), blocking TLR4 signaling and reducing TNF- α and IL-6 production. This prevents excessive inflammation [62].

Prostaglandin E₂ (PGE₂) Secreted by *Trichuris suis*, particularly in the L4 larval stage suppresses pro-inflammatory cytokines (e.g., TNF- α , IL-12) and alters chemokine expression in human dendritic cells and mimics host lipid signaling to promote anti-inflammatory effects [63]. *Trichuris suis* L1 larvae secrete chitinase that demonstrated significant efficacy in ameliorating allergic airway inflammation in a murine ovalbumin (OVA)-induced asthma model. This chitinase exerted its effects by suppressing eosinophil recruitment to the lungs, downregulating eosinophil-attracting chemokines, and expanding RELM α^+ interstitial macrophages (cells associated with tissue repair and immune regulation). Structural analyses via X-ray

crystallography revealed that the *T. suis* chitinase shares a high degree of structural homology with murine acidic mammalian chitinase (AMCase), including a unique dimer-forming capability that may enhance its functional stability. These observations support the hypothesis that *T. suis* chitinase may act through molecular mimicry to dampen host inflammatory responses and represents a promising candidate for therapeutic development in allergic and inflammatory diseases.

Extraction of HDPs:

A wide variety of biological samples can be used for host defense peptide (HDP) extraction, reflecting the evolutionary conservation and diverse roles of these peptides across life forms.

Source Type	Example Samples	Reference
Human/Animal	Skin, gut, blood, neutrophils, lymph nodes	66, 67, 68
Plant	Roots, stems, leaves, seeds, flowers	69, 70
Invertebrates	Insect hemolymph, mollusk tissues	70, 71
Helminths	Egg extracts	73
Cell Culture	Conditioned media from epithelial/immune cells	72

To extract host defense peptides (HDPs) from tissues effectively, several protein extraction techniques can be used to extract, isolate and characterize these peptides.

Tissue disruption

Trizol-based extraction: Used to isolate proteins/peptides alongside RNA/DNA. Trizol disrupts cells and separates biomolecules into organic and aqueous phases, enabling peptide recovery from the interphase or phenol phase.

Bead beating: Mechanical lysis method using beads to homogenize tissue, often compared with Trizol for efficiency in breaking cell membranes and releasing HDPs.

Peptide enrichment can be done by leveraging the cationic nature of the cations. Negatively charged resins can be used to capture the positively charged HDPs and can be eluted by buffer with increasing salt concentration.

Qualitative and Quantitative analysis of HDPs

One-dimensional polyacrylamide gel electrophoresis (1D PAGE) is a qualitative technique commonly used to separate proteins based on their molecular weight. Proteins are

denatured with SDS to provide a uniform negative charge, then subjected to an electric field through a polyacrylamide gel, allowing smaller proteins to migrate faster than larger ones. This results in distinct bands, each representing proteins of similar size. 1D PAGE enables visual assessment of protein expression, purity, and complexity, and serves as a preparative step for downstream analyses like Western blotting or mass spectrometry. While it does not provide precise quantification, it is essential for protein profiling and band selection for further identification.

The Bradford assay is a rapid and widely used colorimetric method for quantifying and estimating the concentration of proteins in a solution. It is based on the binding of Coomassie Brilliant Blue G-250 dye to proteins, particularly to basic (especially arginine) and aromatic amino acid residues. When the dye binds to a protein, it undergoes a spectral shift from the reddish-brown to a blue form. This blue complex is proportional to the amount of protein present, and the intensity of the color can be measured using a spectrophotometer. The Bradford assay is quick, requires no heating or incubation, and provides results within minutes. Its simplicity, speed, and relatively high sensitivity make it a preferred method for routine protein quantification in research laboratories.

The **Bicinchoninic Acid (BCA) assay** is a widely used colorimetric method for the quantification of total protein concentration. It is based on the reduction of cupric ions (Cu^{2+}) to cuprous ions (Cu^+) under alkaline conditions, followed by the formation of a purple-colored complex between Cu^+ and bicinchoninic acid, which absorbs light at 562 nm. The BCA assay relies on the biuret reaction, where peptide bonds and certain amino acid side chains (particularly cysteine, tyrosine, and tryptophan) reduce Cu^{2+} to Cu^+ in an alkaline environment. The resulting Cu^+ then forms a stable, water-soluble purple complex with two molecules of bicinchoninic acid. The intensity of the color is directly proportional to the amount of Cu^+ , and hence, to the concentration of peptide or protein present in the sample.

Characterization of HDP profiles

In order to uncover how these peptides interact with microbial membranes or immune cells, whether they kill pathogens directly, modulate immune responses, or both, it is important to characterize these HDPs. It can help us gain insights into its potential application in health care and clinical application like its selectivity, potency and toxicity. Detailed characterization help us develop analogs that are stable and has enhanced therapeutic values.

1. Mass Spectrometry (MS) and (MS/MS):

Mass spectrometry is the cornerstone of peptidomics research. It works by ionizing peptide molecules, then separating them based on their mass-to-charge ratio (m/z). In a typical workflow, peptides are first ionized using methods such as ESI (Electrospray Ionization), and then detected in a mass analyzer. The result is a spectrum showing peaks corresponding to the Host defense peptides. These spectra are computationally matched against peptide or protein databases to deduce identity and sequence. When coupled with liquid chromatography (LC-MS/MS), it allows excellent separation, quantification, and identification of complex peptide mixtures with high sensitivity, specificity, and throughput.

2. Peptide Mass Fingerprinting (PMF):

Peptide mass fingerprinting is an older but reliable technique for protein identification based on their peptide products. First, a purified protein is digested into peptides using a specific protease (typically trypsin). The resulting peptide masses are then measured using MS. This produces a unique set of peptide masses a "fingerprint" that can be compared against theoretical fingerprints from protein sequence databases. While PMF does not sequence peptides directly, it's particularly useful for identifying proteins from simpler mixtures or single bands excised from gels. It's fast and effective for known proteins but less suitable for novel peptides or complex samples.

3. Edman Degradation:

Edman degradation is a classical method of peptide sequencing. It sequentially removes one amino acid at a time from the N-terminal end of the peptide, identifying it through chemical derivatization and chromatography. This process is repeated cycle by cycle to determine the order of amino acids. It is highly accurate for short peptides like the HDPs, and remains valuable for confirmatory sequencing and for validating peptides .

4. MALDI-TOF (Matrix-Assisted Laser Desorption/Ionization Time-of-Flight):

MALDI-TOF is a soft ionization technique commonly used in peptide and protein analysis. In this method, peptides are mixed with a matrix and applied to a metal target. A laser pulse ionizes the sample, and the ions are accelerated through a time-of-flight analyzer. Because smaller ions travel faster than larger ones, the time it takes to reach the detector correlates with the peptide's mass. MALDI-TOF is especially good for analyzing peptide mixtures, determining molecular weights, and generating mass fingerprints.

Anti-Microbial and Cell-Based assays:**Agar Well Diffusion Assay:**

The agar well diffusion method is a simple yet effective qualitative assay used to evaluate the antimicrobial properties of compounds such as Antibiotics, peptides or extracts. In this technique, a microbial suspension is inoculated on the surface of an agar plate to create a bacterial lawn. Wells are then punched into the agar using a sterile cork-boreer, and each well is filled with a defined volume and concentration of the extracted HDPs[74,75].

During incubation, the compound diffuses radially from the well into the agar medium. If the HDP possesses antimicrobial activity, a clear zone of inhibition appears around the well, indicating effective microbial suppression. The diameter of this zone provides a semi-quantitative measure of the compound's activity [76].

Broth Dilution Assay and Minimum Inhibitory Concentration (MIC):

The broth dilution assay provides a quantitative evaluation of antimicrobial activity by determining the **minimum inhibitory concentration (MIC)** i.e., the lowest concentration of a compound that visibly inhibits microbial growth. This method is performed by preparing serial dilutions of the peptide of interest in a liquid nutrient broth, followed by inoculation with a standardized concentration of the target microorganism.

After incubation, microbial growth is assessed either visually or spectrophotometrically. Wells or tubes with no visible turbidity indicate inhibition of bacterial replication. The MIC offers precise information about the bacteriostatic potential of the compound. This assay is considered a gold standard in antimicrobial drug testing[77,78].

ELISA – Enzyme-linked immunosorbent assay

The basic principle of ELISA relies on reading the detectable signal(usually a color change)proportional to the amount of antigen–antibody interactions in the well.ELISA can be done to measure the quantity of inflammatory regulators like cytokine or chemokine secreted from immune cells such as peripheral blood mononuclear cells (PBMCs) after peptide treatment [79]. ELISA is commonly used for quantifying specific peptide .

Multiplex Bead Arrays:

The method utilizes microscopic polystyrene or magnetic beads, each coated with specific capture antibodies that corresponds to a specific target analyte and uniquely labeled with a fluorescent signature. When a sample (such as plasma or cell culture supernatant) is incubated

with the bead mixture, target peptides/proteins bind to their corresponding antibody-coated beads. The beads are then analyzed using a specialized flow cytometry-based platforms for fluorescence. The fluorescence intensity correlates with the concentration of the target peptide.

This multiplex bead arrays can quantify multiple cytokines or immunomodulatory proteins simultaneously in a single well.

Reporter Gene Assays:

These involve **engineered immune cells** that express a **reporter gene** under the control of an immune-responsive promoter . Upon stimulation by immunomodulatory peptides, **activation of specific signaling pathways** results in reporter expression, providing a real-time readout of immune pathway engagement.

Biofilm and Antimicrobial Activity Assays:

For peptides with dual immunomodulatory and antimicrobial properties, biofilm inhibition and immune modulation (e.g., suppression of LPS-induced cytokines) can be measured in parallel [79].

Challenges Limiting the Clinical Application of Host Defense Peptides (HDPs):

1. **Protease Susceptibility:** HDPs are prone to degradation by proteases due to their L-amino acid composition, reducing their stability, bioavailability, and circulation time in the body.
2. **Rapid Clearance:** Their small molecular size leads to quick elimination from the body via kidney filtration and the reticuloendothelial system.
3. **Cytotoxicity:** Many HDPs exhibit toxicity toward host cells, potentially causing systemic toxicity. This is often linked to their hydrophobic domains that can disrupt mammalian cell membranes.
4. **Salt Sensitivity:** The charged nature of HDPs makes their antimicrobial activity vulnerable to inhibition in physiological salt concentrations.
5. **Emergence of Resistance:** Despite limited use, some bacterial resistance mechanisms against HDPs have been reported. These include:
6. **Limited Specificity of Resistance Mechanisms:** The resistance mechanisms tend to confer only moderate and non-specific resistance, but their presence still poses a concern for long-term efficacy.

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DIFFERENT FARMING TECHNIQUES FOR SEAWEED CULTURE IN INDIA

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Introduction

Seaweeds are macrophytic algae, a primitive type of plants lacking true roots, stems and leaves. Seaweeds are wonder plants of the sea, the new renewable source of food, energy, chemicals and medicines with manifold nutritional, industrial, biomedical, agriculture and personal care applications. Seaweeds are also termed as the 'Medical Food of the 21st Century' as they are being used as laxatives, for making pharmaceutical capsules, in treatment of goiter, cancer, bone-replacement therapy and in cardiovascular surgeries. The global diversity of seaweeds consists of about 6000 species of red seaweeds, 2000 species of brown seaweeds and 1200 species of green seaweeds, of which 210 species are commercially important and 65 % of which are used as human food. The seaweed species diversity occurs maximum in the temperate regions of the world, especially Japan and southern Australia.

Resources :

Seaweeds are abundant along the Tamil Nadu and Gujarat coasts and around Lakshadweep and Andaman & Nicobar Islands. Rich seaweed beds occur around Mumbai, Ratnagiri, Goa, Karwar, Varkala, Vizhinjam and Pulicat in Tamil Nadu, Andhra Pradesh and Chilka in Orissa.

Based on pigmentation & morphology: 3 groups

1. The Chlorophyta(Green algae)
2. The Phaeophyta(Brown algae)
3. The Rhodophyta(Red algae)
 - Red seaweeds: sub-tropical & tropical waters
 - Brown seaweeds: cooler, temperate waters

Some commercially important seaweeds :

- *Kappaphycus alvarezii*
- *Gelidiella acerosa*
- *Gelidium*
- *Gracilaria edulis*
- *Gracillaria dura*
- *G.indica*
- *G. fergusonii*
- *Sargassum wightii*
- *Turbinaria conoides*
- *Acanthophora spicifera*
- *Ulva lactuca*
- *Caulerpa racemosa*

***Kappaphycus alvarezii*:**

- Grows profusely in sandy and rocky bottom
- Salinity range : 28-33 ppt
- Temperature: 30 to 33 °C
- Seed of 150 g grows to 600 grams in 45 days
- Mandapam, Rameswaram, Pudukottai, Tuticorin, Tanjore and Cuddalore
- the most important commercial sources of [carrageenans](#)
- *Kappaphycus alvarezii* cultivated because of High return on investment



***Gelidiella acerosa*:**

- Agar yielding red algae
- Cultured in coir rope frames, coral stones, nylon rope nets in GOM and Palk Bay



- 60 days of culture period
- Higher production was observed in coral stone method

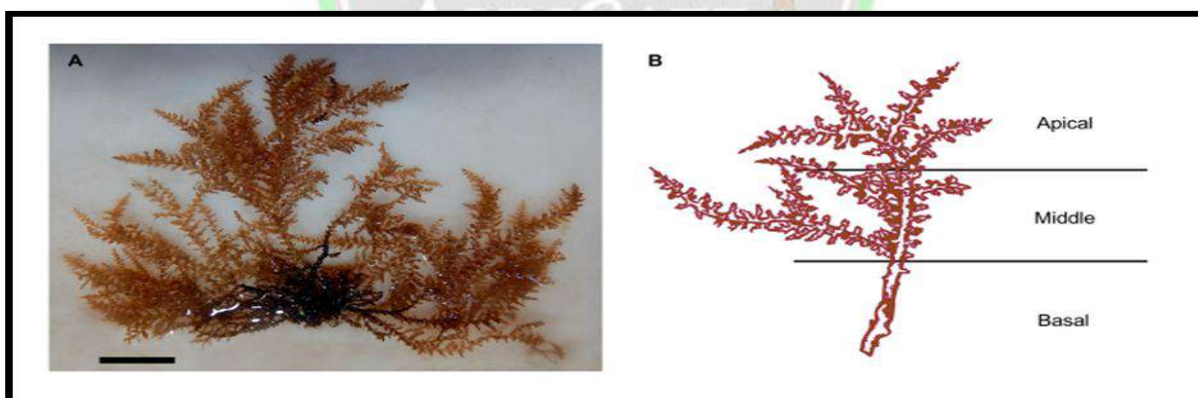
***Gracilaria edulis*:**

- Cultured in coir rope frames, coral stones, nylon rope nets, nylon monolines in GOM and Palk Bay
- 3.5kg/m/yr was obtained in monoline ropes
- 120 tones was harvested in 1 hac. area nets
- These experiments showed that *Gracilaria edulis* could be successfully cultivated on commercial scale throughout the year in the Gulf of Mannar side and during June to September in Palk Bay side of Mandapam area.



***Acanthophora spicifera*:**

- This carrageenan yielding red algae was cultivated by CMFRI in near shore areas of hare island near Mandapam by vegetative propagation method.
- An increase of 2.6 fold occur in 25 days.
- An yield of 3.6 fold increase after 45 days in the first harvest and of more than 2 fold

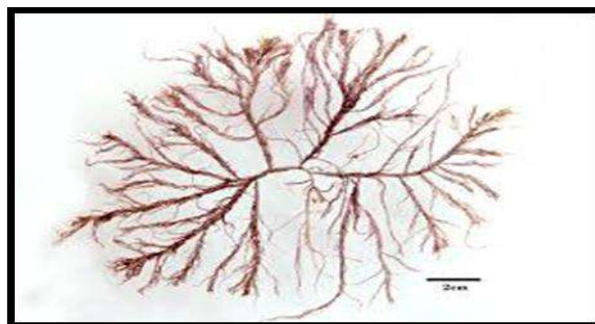


increase after another 1 month in second harvest was obtained from culture pond in Mandapam

Hypnea musciformis

- This carrageenan yielding red alga was cultivated by the CSMCRI in the lagoon of Krusadai Island.
- Vegetative fragments of the plants were used as seed material and they were cultured on long line ropes.

- Fourfold increase in biomass was obtained after 25 days growth.



Methods of seaweed cultivation:

Selection of Site for Seaweed Cultivation:

- shallow coastal waters of maritime States
- Stable seawater with not less than 30 ppt salinity
- Sandy/ rocky bottom with transparent water
- Ideal temperature 26-30 °C.
- The area should have minimum 1.0 m water depth during low tide.
- Area with mild water currents are preferred.
- Don't choose a place where the bottom is soft and muddy; in these places, there is no current and the water is stagnant.

Avoid places where there are lots of coral heads because they attract small fish that will graze on the seaweed.

Species	Culture technology
<i>Gelidiella acerosa</i>	Bottom-culture method using coral stone as a substratum
<i>Gracilaria edulis</i>	Longline rope method using coir rope as substrate or Single Rope Floating Raft Technique (SRFT) method
<i>Hypnea valentiae</i>	Monoline or Longline method using vegetative fragments
<i>G. dura</i>	Monoline or Longline & Floating raft method using vegetative fragments
<i>G. debilis</i>	Floating raft method using vegetative fragments

1) Bottom culture:

- In bottom of sea, ponds, canals & onshore tanks
- In chile: seed planted directly at the bottom sand in inter-tidal region.

- In USA: fragments of *G.verrucosa* sowed in net pens in sea.
- In India: by winding round seeded nylon twines to nails fixed on coral stones.



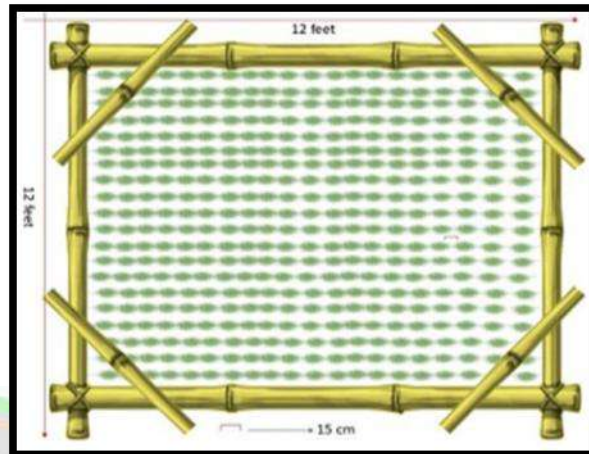
2) Off-bottom Method

- Wooden stakes are driven into the sea bottom 20 to 25 centimeters apart from each other in straight rows.
- The stakes should be 5 to 10 centimeter in diameter and 1 or 1.5 meter long. At least 0.5 meter of the stake should be driven into the sand to make them secure.
- A 3 millimeter thick polypropylene rope 5 meters long is firmly stretched between two stakes.
- Attached to the 3 millimeter rope (line) are 30 pieces of polypropylene strings. Each of your planting material (seed), the size of the palm of your hand (150 grams), is tied to the raffia strings.
- The 3 millimeter rope, is suspended at least 20 to 30 centimeters from the sea bottom to prevent the growing seaweed from being tossed on the sand and 20 to 30 centimeters below the water surface at low tide to avoid the seaweeds from being exposed to direct sun light. Direct sun light will kill the exposed parts.

Floating Bamboo raft method:



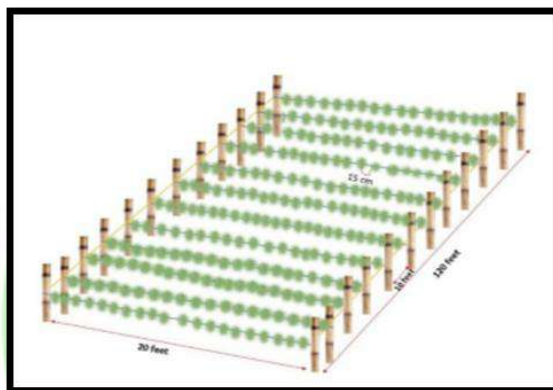
- Floating bamboo raft method is ideal in locations which are calm and shallow.
- Floating rafts are made up of bamboo (3-4 inch) frame with dimensions of 12 feet × feet for mainframe and 4 feet x 4 feet for diagonals.
- In each raft, around 20 polypropylene-twisted ropes (3 mm) are used for plantation.
- Around 150–200 grams of seaweed fragments are tied at a spacing of 15 cm along the length.
- A total of 20 seaweed fragments are tied in a single rope.
- The total seed requirement per raft is 60 – 80 kg.
- In order to avoid grazing by herbivorous fishes, fish net of 4m x 4m size is tied at the bottom of the raft.
- A 15 kg anchor is used to position a cluster of 10 rafts in the near shore area at a depth of 1.0 to 1.5 m during normal season and during rough season the depending upon the species same cluster must be positioned using 2-3 anchors.
 - Harvesting can be done after 45-60 days. ★



3) Longline or monoline method:

- Longline method is ideal for areas with moderate wave action, shallow depth, and with less presence of herbivorous fishes.

- A rectangular seaweed farming area (120 feet length and 20 feet width) made up of 24 casuarina poles (10 feet length and 3- 4-inch dia each) form a unit.
- On one side, 12 casuarina poles are placed at 10 feet intervals and similar structure is erected parallelly 20 feet away.
- The poles are interconnected using a 6mm rope and the seaweed seedling rope is fastened to this.
- Around 150 grams of seaweed fragments are tied at a spacing of 15 cm along the length of a rope and a single rope contains around 40 fragments.
- The total seed requirement per rope is 6 kg and for entire segment is 60 kg.



- A total of 10 ropes (1 monoline unit) is equivalent to one bamboo raft in production.
- A fencing is made using HDPE fishing net to avoiding drifting and used PET bottles are tied on each rope for increasing the floatability.
- Harvesting can be done after 45-60 days depending upon the species.



4) Tube net method :

- Tube net method can be adopted in locations with higher wave action.
- Tube nets having a length of 25 m and a diameter of 10 cm are made from HDPE nets having mesh size of 1.5 cm.
- These are kept floating in the water column below the surface .
- The seed material of 10-15 kg is loaded into the tubes with the aid of a 1-1.5 m long plastic pipe of lesser diameter than that of tube net.
- The plastic pipe is inserted into the tube net and the entire tube is pulled down, so that the mouth of plastic pipe stands out of the tube.
- The tube net is pulled down from the bottom of the plastic pipe carefully, in such a way that seedling material gets loaded into the tube sequentially leaving no gap between the seedlings.
- Both the ends of tube nets are closed to avoid splitting.
- The tubenets are positioned in the sea firmly with the help of anchors and floats.
- Anchor stones of about 30 kg are used.
- 4 tube-net units are equivalent to one bamboo raft in terms of production.
- In addition, tube nets can also be attached to rafts.



5) NET BAG METHOD:

ADVANTAGES

- Growth-high
- No loss material – drifting
- Minimum Grazing
- Withstand any adversed condition
- No accumulation of metabolic waste – Free water circulation

- May be used as seed material

DISADVANTAGES

- Cost of cultivation is higher
- Need more manpower



6) OPEN CULTURE:

Advantages :

- No accumulation of metabolic waste
- Easy method for large scale cultivation
- Optimum Space available for free growth
- High growth rate (>12%/day)

Disadvantages:

- Heavy loss of material (drifting rate is 30-40%)
- Grazing is more (>20%)
- Mechanical damage of the plant
- Cannot be used as seed material

7) Cage culture:

- Floating Method is suitable in shallow (not less than 0.75 m) to deeper areas with moderate water current.
- A floating cage holds a lot of seaweed and protects it from being eaten.
- A seaweed pen also protects the seaweed from being eaten by fish.

8) RACEWAY CULTURE:

- Land based culture system
- Limitation of natural shoreline.

- Production can be continued even during rainy season by protecting raceway with translucent
- Fast growing tropical strain *Gracilaria* is cultivated in raceway (ponds with water current) in Philippines .



9) Greenhouse culture:

- In Canada *Chondrus crispus* and *Gracilaria* are cultured in greenhouses by manipulating temperature and light.
- In India also different important seaweeds have been attempted in onshore condition with



running seawater system and by providing aeration.

Maintenance of Rafts and Harvesting:

Maintenance of rafts would be done by the beneficiaries themselves, i.e. SHGs/ Fisherman Society, fish farmers. One person/beneficiary can handle a single raft in a day. Seaweed cultivated on rafts can be harvested every 45-60 days. Seaweed removed from the rafts will be dried on a clean surface and marketed to the seaweed processing industries .

MILLETS FOR SUSTAINABLE AGRICULTURE: ADDRESSING CHALLENGES AND UNLOCKING OPPORTUNITIES FOR CLIMATE RESILIENCE AND NUTRITIONAL SECURITY**Article ID: AG-VO5-I05-26**

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Abstract

Millets, ancient drought-tolerant grains with a history of over 10,000 years, have gained renewed attention due to their resilience to climate change, high nutritional value, and adaptability to diverse agro-ecological conditions. These grains, including pearl millet, finger millet, and proso millet, are increasingly recognized as a sustainable alternative to traditional cereals like rice and maize. Millets offer significant advantages in regions facing water scarcity, erratic weather, and food insecurity, especially in arid and semi-arid areas. Millets are highly nutritious, providing moderate-to-high protein, essential amino acids, dietary fiber, and a range of vitamins and minerals such as B vitamins, magnesium, phosphorus, and manganese. They are also rich in antioxidants like carotenoids and phenolic compounds, contributing to reduced oxidative stress and lower risk of chronic diseases. Their ability to withstand high temperatures and drought makes them an ideal crop in the context of global climate change, offering a solution to the growing challenges of food security. Despite their potential, millet production faces several challenges, including low productivity, limited market demand, and reduced consumption due to urbanization and preference for major cereals like wheat and rice. Moreover, issues such as difficult processing, storage problems, and policy neglect hinder the widespread adoption of millets. Biofortification efforts, such as iron-biofortified pearl millet and zinc-biofortified finger

millet, aim to address malnutrition and improve health outcomes, particularly in low-income countries. Efforts to strengthen the millet value chain, enhance seed production, improve agronomic practices, and promote millet consumption through various initiatives, including the UN's declaration of 2023 as the International Year of Millets, are helping to raise awareness and boost millet production. By fostering research, investment, and policy support, millets can play a crucial role in achieving food security, enhancing nutrition, and promoting sustainable agriculture globally.

Key words: Biofortification food security sustainable agriculture.

Introduction

Millets are ancient, drought-tolerant, small-seeded grains with a history of over 10,000 years, originating from Africa and the Indian subcontinent. Evidence of millet consumption from around 8000 BC was found in Shandong, China. Due to their adaptability to diverse climates, millets became essential to early agriculture, particularly in regions with food scarcity and unpredictable weather. Today, challenges like climate change, water scarcity, population growth, and rising food prices threaten global agriculture and food security, particularly in arid and semi-arid regions. Millets, which include pearl millet (*Pennisetum glaucum*), finger millet (*Eleusine coracana*), kodo millet (*Paspalum setaceum*), proso millet (*Panicum miliaceum*), foxtail millet (*Setaria italica*), little millet (*Panicum sumatrense*), browntop millet (*Brachiaria ramosa*), and barnyard millet (*Echinochloa utilis*), offer sustainable solutions. Along with maize, sorghum, oats, and barley, they are categorized as coarse cereals.

Currently, developing countries produce and consume about 97% of the world's millets, with global output recorded at 28.27 million tons in 2019, 30.83 million tons in 2020, and 30.09 million tons in 2021. Millets are highly nutritious. They have moderate-to-high protein content and are complete proteins, containing all essential amino acids. Their high dietary fiber content promotes digestive health and reduces gastrointestinal disorders. Millets are also rich in B vitamins—riboflavin (B2), thiamine (B1), and niacin (B3)—essential for energy metabolism and nerve function. Important minerals such as magnesium, phosphorus, and manganese in millets support bone health and antioxidant defences. Additionally, millets are abundant in antioxidants like carotenoids and phenolic compounds, which help reduce oxidative stress and the risk of chronic diseases. They are low in fat, with most fats being unsaturated, benefiting heart health.

A key advantage of millets is their resistance to abiotic stresses such as drought and high temperatures, supported by deep root systems that extract water and nutrients from deeper soil layers. In the context of global climate change, this resilience makes millets a promising alternative to traditional cereals. India is currently the largest millet producer, especially of finger millet and pearl millet, driven by cultural and culinary significance. Nigeria, Niger, and Sudan are also major producers. However, the preference for wheat and rice has reduced millet cultivation globally. Recently, there has been renewed interest in millets to enhance nutrition and promote sustainable farming. Recognizing their importance, the UN and FAO declared 2023 the International Year of Millets. This initiative aims to raise awareness of millets' role in food security, nutrition, sustainable agriculture, and biodiversity conservation, encouraging investment in millet research and production. Promoting millets is seen as a vital step toward a healthier, more resilient, and food-secure future.

CHALLENGES IN MILLET PRODUCTION AND CONSUMPTION

Traditional Role and Cultivation Practices

Millets have historically been a crucial part of India's farming systems and diets, especially in drylands with low input requirements. Traditionally, they were consumed as porridge, flatbreads, fermented beverages, dumplings, and combined with vegetables or pulses (P. P. Rao et al., 2006). Only 10%–15% of millet cultivation areas are irrigated, in contrast to 95% for wheat and 60% for rice (MAFW, 2023), making millet productivity highly dependent on rainfall and vulnerable to climate variability.

Biofortification for Nutritional Improvement

Biofortification has emerged as a major strategy to address malnutrition by enhancing millets with vital micronutrients through breeding and biotechnology.

- **Iron-biofortified pearl millet** helps combat iron deficiency anaemia by increasing iron intake, thus improving haemoglobin levels and productivity.
- **Zinc-biofortified finger millet** addresses zinc deficiency, boosting immunity, wound healing, and development in vulnerable groups.
- **Vitamin A-biofortified proso millet** aims to reduce vitamin A deficiency, which is critical for immune function and vision, particularly in low- and middle-income countries.

Low Productivity and Market Constraints

Millet yields remain lower compared to major cereals: sorghum and pearl millet yield around 1.0 and 1.4 t/ha, respectively, compared to wheat (3.5 t/ha), maize (3.2 t/ha), and rice (2.8 t/ha). In years of good rainfall, market glut and minimal government procurement lead to poor price realization for farmers discouraging millet cultivation.

Declining Consumption Patterns

Urbanization and the Public Distribution System (PDS) favouring subsidized wheat and rice have drastically reduced per capita millet consumption from 30.9 kg in 1960 to 3.9 kg in 2022. Additionally, millets are often stigmatized as "poor people's food," limiting their appeal among the middle and upper classes.

Processing and Storage Challenges

Primary processing of millets is difficult due to small seed size, thick seed coats, and the presence of anti-nutrients like tannins and phytates. Processed millet grains have a poor shelf life because of lipid oxidation and enzymatic activity leading to rancidity. Machinery efficiency issues and lack of uniform decortication technologies further complicate processing.

Policy and Institutional Neglect

Millets have received less policy and research attention compared to rice and wheat. While MSP is announced for major millets, actual procurement remains minimal, especially for minor millets, limiting farmers' incentives. ★ ★ ★ ★

OPPORTUNITIES FOR MILLETS IN AGRICULTURE AND NUTRITION

❖ Climate Resilience of Millets

Millets are naturally adapted to harsh climates, making them a resilient crop in the face of climate change. With their ability to withstand droughts and high temperatures, millets, such as sorghum and pearl millet, can survive temperatures up to 42°C. These attributes make them a sustainable alternative to more vulnerable crops like rice and maize, especially as global climate patterns change and growing seasons shorten. Their low resource requirements, including reduced water and fertilizer needs, position millets as ideal candidates for future farming, particularly in regions facing climate stress.

❖ Contribution to Sustainable Development Goals (SDGs)

Millets significantly contribute to multiple Sustainable Development Goals (SDGs). They play a crucial role in achieving Zero Hunger (SDG 2) and Good Health (SDG 3) by

providing a nutrient-rich food source high in protein, iron, and antioxidants. Millets also support Climate Action (SDG 13) through their resilience to adverse climate conditions and by reducing the carbon footprint of agriculture. Additionally, their low fertilizer requirements and tolerance to pests align with Responsible Consumption (SDG 12), promoting sustainable agricultural practices.

❖ **Role in Nutritional Security**

Biofortification of millets addresses micronutrient deficiencies, particularly iron deficiency, in vulnerable populations. Iron-biofortified varieties of pearl millet have proven effective in reducing iron deficiency among schoolchildren in India. Millets are naturally rich in essential nutrients like protein, fiber, calcium, and magnesium, making them an excellent dietary supplement. Minor millets, in particular, contain amino acids lacking in common staples like rice and wheat. Though millets contain some antinutrients, traditional processing methods like fermentation and roasting enhance their nutritional value. Additionally, they are increasingly incorporated into functional foods like bread and cookies, which can improve insulin sensitivity and lower cholesterol.

❖ **Intensifying Research on Millets**

Historically, research on millets has been limited compared to major cereals like rice and wheat. However, the establishment of organizations such as the Indian Institute of Millet Research (IIMR) and the Global Centre of Excellence on Millets has accelerated research efforts. These institutions focus on improving millet productivity, value addition, and global competitiveness. Genetic improvement through large germplasm collections and hybrid breeding is enhancing millet yields and stress tolerance. Research also emphasizes biofortification, with high-iron and high-zinc varieties being developed to address nutritional deficiencies in regions such as South Asia and Sub-Saharan Africa.

❖ **Strengthening Seed Chain and Agronomic Management**

India has made substantial progress in strengthening millet seed production. Over 220 millet cultivars have been released, and the establishment of breeder seed production centers has increased seed availability to farmers. With the National Food Security Mission's support, over 82,000 tonnes of quality seeds were produced in 2022-2023, surpassing the demand of 54,000 tonnes. Additionally, adopting soil and moisture conservation techniques, integrated nutrient management, and pest control has significantly improved millet yields.

Studies have shown that such practices can increase grain yields by up to 113% and fodder yields by over 100%.

❖ **Postharvest Management**

Postharvest processing of millets faces challenges due to their unique morphological characteristics. Special machinery for threshing, dehulling, and processing has been developed to address these issues. However, pearl millet, in particular, is prone to rancidity. Researchers are exploring methods like hydrothermal treatments to reduce rancidity and improve the shelf life of millet products. These innovations enhance millet grain quality and storage, which is crucial for its marketability and nutrition.

❖ **Promoting Millet Consumption**

The rising health awareness among consumers is driving the demand for millets, especially due to their gluten-free nature, making them suitable for individuals with gluten intolerance. The promotion of millets in the Public Distribution System (PDS) at subsidized rates can increase consumption, particularly among low-income groups. Regional approaches can be used to promote millet varieties based on local preferences. Additionally, value-added millet products, such as millet flour, flakes, and snacks, can cater to urban and high-income households, creating new market opportunities.

❖ **Strengthening the Millet Value Chain**

To enhance millet production and consumption, a robust value chain is essential. Government initiatives, such as the promotion of Farmer Producer Organizations (FPOs), aim to improve market access for farmers and integrate them into modern supply chains. Subsidies for mechanized processing and value-added millet products further strengthen this value chain. Research institutions and global partnerships, such as the UN's declaration of 2023 as the International Year of Millets, have also played a significant role in raising awareness about the nutritional and climate-resilient benefits of millets. These efforts contribute to building a sustainable and profitable millet supply chain.

Conclusion

Millets are a highly resilient and nutritious crop with immense potential for addressing global challenges such as climate change, food insecurity, and malnutrition. Despite their long history of cultivation in regions like India, millets face challenges in terms of low productivity, market constraints, and declining consumption due to the growing preference for more

mainstream crops like rice and wheat. However, their inherent resilience to drought and high temperatures makes them an ideal alternative for regions experiencing climate stress. Their ability to thrive with minimal water and fertilizers, coupled with their rich nutritional profile, positions millets as a sustainable crop that can contribute to multiple Sustainable Development Goals (SDGs), including Zero Hunger, Good Health, and Climate Action. Biofortification initiatives, such as iron, zinc, and vitamin A-enriched varieties, are proving effective in combating micronutrient deficiencies, especially in vulnerable populations. Promoting millet consumption through public awareness campaigns, subsidized distribution, and the introduction of value-added millet products can further strengthen demand and boost production. Investments in research, improved agronomic practices, and strengthened seed systems are critical to increasing millet yields and making them more competitive in global markets. By fostering policy support, market access, and innovation in processing technologies, millets can play a significant role in ensuring food security and contributing to a sustainable, climate-resilient future.

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PRACTICES PALMYRA PALM JAGGERY PRODUCTION: CURRENT, CHALLENGES AND FUTURE POTENTIAL

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Abstract

The Palmyra palm (*Borassus flabellifer* L.) is a versatile and culturally significant tree commonly found in tropical regions, particularly in South India. It offers numerous benefits, among which the production of palm jaggery stands out due to its nutritional value and traditional importance. Palm jaggery (karupatti), a natural sweetener, is derived from the sap of the Palmyra tree (known as pathaneer) through a diligent process that involves both skill and precision. The sap collection begins only after the tree matures, typically after 15 years. Using traditional wooden tools, (v shaped tool) the spadix of the palm is cut in the early morning and evening about 2 to 3 days. After two days, mud pots are tied below the inflorescence to collect the sap, starting with 0.5 to 1 litre per day, increasing gradually. The production continues with settling, clarification, boiling at approximately 500°C and molding into blocks. Palm jaggery is rich in minerals, iron, and antioxidants, making it a healthier alternative to refined sugar. Though the process remains traditional, it holds great potential for modernization and scale-up to support rural livelihoods, especially in regions like Senbagathoppu region of Kalugampottal Pannai in the Srivilliputhur taluk of the Virudhunagar district. This article look into the proceesing of palm jaggery and it's benefits and future scope of jaggery production.

Keywords

Palm tree, karupatti, traditional wooden tool, healthier alternative, rural livelihood, future scope.

Introduction

The Palmyra palm tree (*Borassus flabellifer* L.) is a celestial tree which is grown in rainfed land of southern regions of Tamil Nadu. Each and every part of palmyra tree is beneficial, that is the palm leaves are used to make hand craft like (basket, hat, floor decoration), and its trunk used to make furniture and the palmyra palm tree offers nungu and its seeds gives panai kilangu it is rich in fiber content. The male and female inflorescence gives pathaneer after the plantations get 15 years old. The life span of Palmyra palm is exceeding 100years and it gives pathaneer, nungu for about 80 years.



FIG:1 NUNGU AND PANAI KILANGU

This article outlines the uses of the Palmyra palm, the step-by-step production of palm jaggery, Cost economics and its benefits and scope for the future.

SAP COLLECTION TIMING AND HANDLING

The Palmyra palm begins producing pathaneer (sweet sap) only after reaching about 15 years of age. Proper handling is essential to ensure quality and yield. The traditional method begins with the careful cutting of the spadix using a wooden, V-shaped tool (Idukukambu in Tamil) during the early morning and evening. This controlled cutting stimulates the flow of sap. After two days, a mud pot is tied below the cut area to collect the sap. Initially, the tree yields about 0.5 to 1 litre of sap per day, which gradually increases as tapping continues. Sap collection in this study was carried out in the Senbagathoppu (Kalugampottal Pannai) region of

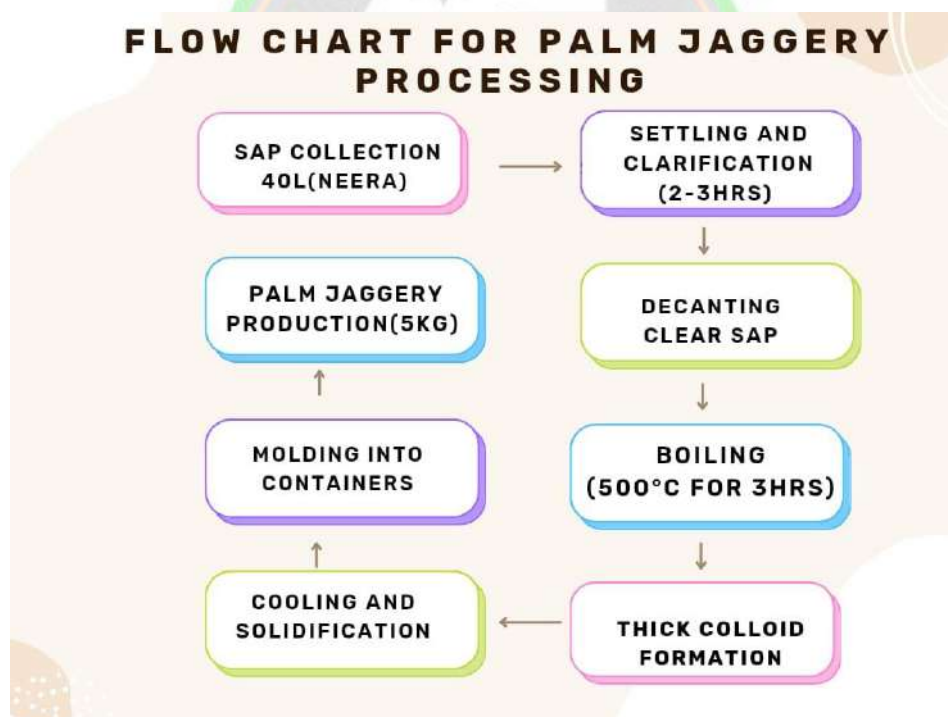
Virudhunagar district, where Palmyra palms are widely cultivated for traditional sweetener production.

PATHANEER (NEERA) COLLECTION TECHNIQUE

To initiate Pathaneer (neera) secretion, the palm spathe (inflorescence) is prepared by daily rubbing and compressing using a V-shaped wooden tool for about five days. During the first 2–3 days, pressing is done before 11:00 AM, and around 2 mm of the spathe is shaved off daily with a curved knife to expose flower buds and enhance sap flow. Cleaned mud pots, coated with slaked lime, are used to prevent early fermentation. The inflorescence is tied with natural fiber, keeping the spines intact. Pathaneer secretion starts early in the morning and lasts for 12–15 days per spathe. The sap is collected in closed pots to avoid contamination.

MATERIALS AND METHODS FOR PROCESSING OF FARM JAGGERY

Here I explain by flow chart the step -by- step preparation of palm jaggery production method is given below.



Sap Collection

Fresh neera (palm sap) was collected from mature Palmyra palm trees during early morning hours using traditional climbing and tapping techniques. The sap was collected in clean earthen or food-grade plastic containers. For every batch, approximately 40 litres of neera were

required to produce 5 kilograms of palm jaggery. The sap was immediately transported to the processing area and kept in a shaded, cool place to avoid fermentation.



FIG:2 PATHANEER SAP COLLECTION

Settling and Clarification

The collected neera (Pathaneer) was allowed to settle in covered containers for 2 to 3 hours at ambient temperature. During this period, calcium carbonate and other suspended solids settled at the bottom of the vessel. Without disturbing the sediment, the clear upper layer was carefully transferred to a boiling vessel using filter.



FIG:3 SETTLING AND CLARIFICATION

Boiling and Concentration

The clarified neera (Pathaneer) was boiled in a large open pan over a traditional wood-fired stove. The liquid was continuously boiled for approximately 3 hours, maintaining an estimated temperature of around 500°C. Gradual evaporation of water led to the thickening of the sap into a viscous, syrupy consistency. Care was taken to stir regularly to avoid scorching and ensure even concentration.



FIG:4 BOILING

Molding

After the boiling process, when the neera reaches a thick, syrupy consistency, it is promptly poured into molds while still hot. In this traditional method, only coconut shells are used as molds, reflecting the deep-rooted cultural practices associated with palm jaggery production. These shells are thoroughly cleaned and lightly greased with a thin layer of edible oil (coconut oil) or ghee to prevent sticking and to provide a smooth surface to the finished product.

Storage

After the full solidification of the jaggery blocks were de-molded and kept at ambient temperature and prevent it from moisture area and contamination. No artificial preservatives are added in these palm jaggery production only we use slaked lime and coconut oil, so that the palm jaggery ensures the natural flavor, nutrients, and shelf life. Proper handling is done the palm jaggery can be stored for 5 months. In storage area they use incandescent light bulb , it helps to kept the room temperature high and it prevents from moisture absorption.



FIG:5 KARUPATTI

BENEFITS OF PALM JAGGERY

- **Nutrient-rich:** Palm jaggery contains minerals such as iron, calcium, magnesium, and potassium which help us to live healthier lifestyle (Upadhyaya & Sonawane, n.d.; Subramanian et al., 2024).
- **Healthier sweetener:** Palm jaggery have a lower glycemic index than refined sugar, it provides a more stable source of energy free from chemical additives (Manisha et al., n.d.).
- **Digestive aid:** Palm jaggery traditionally used after meals, it supports digestive health and gut function and it leads a healthier life style. (Vengaiah et al., n.d.).
- **Supports rural livelihoods:** Palm jaggery production offers employment opportunities to local tappers and small-scale producers that means it makes rural entrepreneurship (Malavizhi, 2022).
- **Eco-friendly:** Made without chemical additives or industrial processing, it represents a sustainable alternative (Ravindra Babu et al., n.d.).

COST ECONOMICS

FOR PALM JAGGERY AND SUGARCANE JAGGERY PRODUCTION

FOR PALM JAGGERY PRODUCTION

Revenue

1. Daily production: 10 kg of palm jaggery
2. Price per kg: ₹250
3. Daily revenue: $10 \text{ kg} \times ₹250/\text{kg} = ₹2,500$
4. Revenue (assuming 180days): $₹2,500 \times 180 = ₹4,50,000$

Variable Costs:

1. Labor wages per day: ₹150
2. Labor wages: $₹150 \times 180 = ₹27,000$
3. Slaked lime (5 kg) for 1 month: ₹500
4. Slaked lime cost (6 months): $₹500 \times 6 = ₹3,000$

Total Variable Costs per year: $₹27,000 + ₹3,000 = ₹30,000$

Fixed Costs:

1. 140 mud pots $\times$ ₹100 per pot: ₹14,000 (assuming this is a one-time investment)
2. Pan cost (6 months): ₹1,250

Profit

1. Daily profit: ₹2,500 - ₹150 (labour) - ₹41.67 (slaked lime) = ₹2,308.33
2. Profit (6 months) ₹4,50,500 - ₹30,000 (variable costs) - ₹1,250 (pan cost) - ₹14,000 (mud pots) = ₹4,04,750

Gross Profit

1. Gross Profit = Revenue - Cost of Goods Sold (COGS)
2. COGS = Variable Costs related to production (labour, slaked lime)
3. Gross Profit (6 months) = ₹4,50,000 - ₹30,000 = ₹4,20,000

Operating Profit

1. Operating Profit = Gross Profit - Operating Expenses (fixed costs)
 2. Operating Expenses = pan cost + mud pot cost = ₹1,250 + ₹14,000 = ₹15,250
- Operating Profit per year = ₹4,20,000 - ₹15,250 = ₹4,04,750

Net Profit

1. Net Profit = Operating Profit - Taxes and Interest
 2. Assuming no taxes and interest, Net Profit = Operating Profit
- Net Profit per year = ₹4,04,750

FOR SUGAR CANE JAGGERY PRODUCTION

Variable Costs:

1. Labour wages for weeding: ₹11,500
 2. Fertilizer: ₹4,500
 3. Sugar cane cutter labour charge: ₹20,000
 4. Labor charges for processing jaggery: ₹810
- Total Variable Costs: ₹11,500 + ₹4,500 + ₹20,000 + ₹810 = ₹36,810

Fixed Costs:

1. Cost of 1 acre production: ₹1,00,000

Revenue:

1. Yield per acre: 28 quintals (1 quintal = 100 kg, so 28 quintals = 2800 kg)
2. Price per kg of sugar jaggery: ₹50
3. Total revenue: 2800 kg × ₹50/kg = ₹1,40,000

Gross Profit:

Gross Profit = Revenue - Total Variable Costs = ₹1,40,000 - ₹36,810 = ₹1,03,190

Operating Profit:

Operating Profit = Gross Profit - Fixed Costs = ₹1,03,190 - ₹1,00,000 = ₹3,190

Net Profit:

Assuming no taxes or interest, Net Profit = Operating Profit = ₹3,190

1. Gross Profit: ₹1,03,190
2. Operating Profit: ₹3,190
3. Net Profit: ₹3,190

Comparison

Parameter	Sugarcane jaggery (in Rs)	Palm jaggery (in Rs)
Revenue per day	1500	2500
Net profit per day	812.60	2308.33
Yield	2800(in kg)/acre	10 kg/day
Labor costs	31500/acre	150/day
Other costs	4500	500+2500
Fixed costs	100000	14000+2500
Gross profit	103190/year	450000/6months
Operating profit	3190/year	404750/6months
Net profit	3190/year	404750/6months

We Conclude that, based on the comparison palm jaggery production appears to be more profitable and cost-effective than sugar cane jaggery production. Palm jaggery production generates more revenue and net profit per day, with lower labor and other costs.

RESEARCH GAPS

Despite its nutritional and economic potential, palm jaggery production remains largely traditional, with limited technological advancements. Standardization of processing parameters, quality control measures, and shelf-life improvement are underexplored. Additionally, scientific studies on the biochemical changes during processing and their impact on health benefits are still limited, indicating a need for further research and innovation

FUTURE SCOPE

There is strong potential to modernize palm jaggery production through improved processing technologies, hygienic practices, and value addition. Research on automation, packaging, shelf-

life extension, and nutritional profiling can enhance its marketability. Promoting palm jaggery in health-conscious and export markets can further boost rural income and sustainable agriculture.

Conclusion

Based on the comparative analysis, palm jaggery production proves to be more profitable and cost-effective than sugarcane jaggery production. It offers higher daily revenue and net profit while requiring lower expenditure on labor and operational inputs. The use of traditional methods and locally available resources further reduces production costs, making it an economically viable and sustainable option for rural communities. Moreover, the increasing demand for natural and chemical-free sweeteners enhances the market potential of palm jaggery, contributing to both livelihood improvement and the preservation of indigenous practices.

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GREEN CHEMISTRY APPROACHES IN PESTICIDE DEVELOPMENT

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Abstract

Green chemistry offers a sustainable approach to pesticide development by reducing environmental impact and human toxicity. This article explores principles such as renewable feedstocks, safer solvents, and design for degradation. Case studies like neem-based insecticides and microbially derived agents demonstrate real-world applications. These eco-friendly alternatives support biodiversity and reduce chemical residues in the environment. Challenges include scalability, product stability, and regulatory adaptation. Future progress relies on innovation, advanced formulation, and supportive policy frameworks.

Introduction

The increasing environmental and health concerns associated with conventional pesticides have highlighted the urgent need for more sustainable alternatives. Green chemistry offers a science-based framework to design and develop pesticides that minimize ecological harm while maintaining agricultural efficacy. By prioritizing non-toxic, biodegradable, and renewable materials, green chemistry emphasizes safer practices across the pesticide lifecycle. Traditional synthesis routes often involve hazardous solvents and by-products, contributing to environmental pollution and resource depletion. In contrast, green pesticide development focuses on atom economy, energy efficiency, and the use of environmentally benign reagents. These approaches help reduce the chemical footprint of agriculture without compromising pest control.

Advances in biotechnology, nanotechnology, and natural product chemistry are enabling novel formulations with targeted action and minimal off-target effects. Such innovations support integrated pest management systems and align with global sustainability goals. The adoption of green chemistry in agrochemical industries is not only a scientific necessity but also a regulatory and ethical imperative. This article explores the principles, methods, and impact of green chemistry in reshaping the future of pesticide development.

PRINCIPLES OF GREEN CHEMISTRY IN PESTICIDE DESIGN:

1. Designing Safer Active Ingredients

Green chemistry advocates for the development of pesticide molecules that target specific pests with minimal toxicity to non-target species, including humans, pollinators, and aquatic organisms. Structural modifications can improve selectivity and reduce side effects, thereby enhancing safety profiles.

2. Use of Renewable Feedstocks

Instead of relying on petroleum-based chemicals, green pesticide synthesis often incorporates renewable raw materials such as plant-derived oils, essential oils, and microbial metabolites. These bio-based inputs reduce dependence on non-renewable resources and are often biodegradable.

3. Reducing Derivatives and Waste

Avoiding unnecessary derivatization (such as blocking or protecting groups) helps streamline the synthesis of pesticide compounds. Fewer reaction steps lead to reduced waste, lower energy consumption, and decreased use of hazardous solvents.

4. Atom Economy and Efficient Synthesis

Atom economy is a core green chemistry concept that measures how well atoms in reactants are incorporated into the final product. In pesticide design, reactions with high atom economy help minimize waste and enhance cost-efficiency.

5. Design for Degradation

Green pesticides are formulated to degrade into non-toxic, environmentally benign substances after fulfilling their pest-control function. This prevents accumulation in soil or water and reduces risks of long-term environmental contamination.

6. Safer Solvent and Reaction Conditions

The use of water or supercritical CO₂ as reaction media replaces volatile organic compounds

(VOCs), which are often flammable and toxic. This not only improves safety in manufacturing but also reduces emissions and pollution.

7. Energy Efficiency

Green pesticide synthesis prioritizes reactions that occur at ambient temperature and pressure, thereby reducing the energy footprint of production. This is especially relevant in industrial-scale synthesis.

8. Real-Time Analysis for Pollution Prevention

In-process monitoring and control technologies help detect by-products and impurities early in the production process, reducing waste and improving the purity and safety of pesticide formulations.

CASE STUDIES:

1. Neem-Based Insecticides

Neem-derived compounds like azadirachtin act as insect growth regulators and antifeedants, showing high selectivity toward pests. They degrade quickly in soil and sunlight, minimizing long-term environmental impact. Neem formulations are non-toxic to humans and beneficial organisms such as bees. The raw materials (seeds and leaves) are renewable, supporting sustainable sourcing. This aligns with green chemistry through biodegradability, safety, and targeted action.

2. Fermentation-Derived Fungicides (Streptomycin & Avermectin)

Streptomycin, produced by *Streptomyces griseus*, controls bacterial plant diseases like fire blight. Avermectins from *Streptomyces avermitilis* target nematodes and insects with low non-target toxicity.

These are synthesized through microbial fermentation, reducing chemical waste and energy use. They are biodegradable and break down safely in soil environments. Such biologically produced agents exemplify green chemistry in pest control.

3. Spinosad – A Bioinsecticide from *Saccharopolyspora spinosa*

Spinosad is a natural insecticide produced by fermenting the soil bacterium *Saccharopolyspora spinosa*.

It targets specific insect pests while posing minimal risk to humans, animals, and beneficial insects.

Its biodegradability ensures low environmental persistence and reduced contamination.

The compound is approved for use in organic farming due to its safety and natural origin. Spinosad exemplifies green chemistry through renewable sourcing, selectivity, and eco-safety.

BENEFITS:

Green chemistry-based pesticides break down quickly in the environment, reducing long-term contamination and ecological disruption. They are designed to minimize accumulation in soil, water, and living organisms, lowering risks of bioaccumulation. These products typically exhibit lower toxicity to humans, reducing health hazards for farmers and consumers. Pollinators and beneficial insects are less affected, supporting biodiversity and natural pest control. Their safer profile leads to improved public trust and acceptance in agricultural practices. Additionally, compliance with stricter environmental and safety regulations becomes easier for manufacturers and farmers.

CHALLENGES AND FUTURE DIRECTION:

While green synthesis methods are environmentally sound, scaling them up for commercial use remains cost-intensive. Many bio-based pesticides face challenges in maintaining stability, shelf-life, and consistent performance in diverse field conditions. Formulation technologies must evolve to improve delivery and persistence without compromising safety. Regulatory systems often lag behind scientific innovation, creating hurdles for the approval of new green products. Future efforts should focus on integrating green chemistry with advanced formulation and policy support for wider adoption.

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TOOLS AND METHODS USED FOR FISH BIOLOGY AND FISH STOCK ASSESSMENT

Article ID: AG-VO5-I05-29**¹Gaurav Kumar*, Radhakrishnan K.V¹., Suman Dey² and Hanuman Prasad Yadav¹,*****Department of Fisheries Resource Management,****²Department of Fisheries Extension****CoF, ANDUA&T Kumarganj, Ayodhya-224229, India*****Corresponding Author Email ID: gauravkumar0639482@gmail.com**

Abstract

This study explores fish feeding habits, reproductive biology, and stock assessment using various analytical techniques. Gut content analysis helped determine dietary patterns, while indices like RGL and GaSI assessed feeding intensity. Reproductive analysis included sex ratio evaluation, spawning season determination, and fecundity estimation. Stock assessment examined growth patterns, mortality rates, and exploitation levels, employing methods like FiSAT II and Virtual Population Analysis. Findings contribute to sustainable fisheries management and conservation efforts.

Keywords: Feeding habits, Reproductive biology, Virtual Population Analysis

1.Introduction

Fish biology is a key foundation for sustainable fisheries, especially in a country like India where fish contributes significantly to nutrition and rural livelihoods. It involves studying the feeding behavior, reproduction, growth, and ecological needs of fish species, which helps us understand how they survive and thrive in their environments. These biological traits are essential for developing responsible fishing practices that protect both fish populations and the ecosystems they inhabit (King, 2007).

One major application of fish biology is in stock assessment, a scientific process that evaluates the condition and population trends of fish stocks using data such as catch rates, mortality, and recruitment. This helps estimate how much fish can be harvested without

depleting the resource. By combining biological information with analytical models, stock assessment provides a scientific basis for fisheries management decisions. This is particularly important in India, where overfishing, habitat loss, and environmental change threaten the sustainability of both inland and marine fisheries (Hilborn & Walters, 1992; FAO, 2018).

2. Food and Feeding Habits

The dietary patterns of fish were investigated through gut content analysis using both qualitative and quantitative approaches. Fish specimens were carefully dissected along the ventral side to access internal organs, including the liver, intestines, and gonads, which were then measured to the nearest millimetre and weighed to the nearest gram. The intestinal contents were gently extracted either by squeezing or pulling and preserved in 5% formalin for further examination.

In qualitative analysis, food items were identified based on their morphological features. Quantitative analysis included several established techniques.

The **Occurrence Method** determined how frequently each food item appeared in the stomachs using the formula:

$$\% \text{ occurrence} = (\text{Number of stomachs containing a specific item} / \text{Total number of stomachs}) \times 100$$

(Hynes, 1950)

The **Numerical Method** calculated the proportion of individual food organisms as:

$$\% \text{ numerical abundance} = (\text{Number of individuals of a food item} / \text{Total number of food organisms}) \times 100$$

In the **Volumetric Method**, the volume of each food component was estimated by water displacement and expressed as:

$$\% \text{ volume} = (\text{Volume of item} / \text{Total volume of gut contents}) \times 100$$

Gravimetric Method involved weighing each food item and expressing its share as:

$$\% \text{ weight} = (\text{Weight of item} / \text{Total weight of gut contents}) \times 100$$

In the **Point Method**, stomach fullness was scored as 100 for full, 75 for $\frac{3}{4}$ full, 50 for $\frac{1}{2}$, 25 for $\frac{1}{4}$ full, and 0 for empty stomachs. Points were then assigned to each food item based on its relative abundance (Pillay, 1952).

To integrate different parameters, two composite indices were used.

The **Index of Relative Importance** (IRI) was calculated following Pinkas *et al.* (1971) as:

$$\text{IRI} = (\%N + \%V) \times \%O$$

Similarly, the **Index of Preponderance** (IP), proposed by Natarajan and Jhingran (1961), was computed as:

$$\text{IPi} = (V_i \times O_i / \sum V_i O_i) \times 100$$

In addition, the **Relative Gut Length** (RGL) was used to understand dietary preferences across different size groups. It was computed using the formula:

$$\text{RGL} = \text{Gut length} / \text{Total body length}$$

(Desai, 1970; Al-Hussaini, 1949)

Herbivorous species typically exhibited higher RGL values. The **Gastro-somatic Index** (GaSI) was used to assess feeding activity, especially during reproductive phases, and calculated as:

$$\text{GaSI} = (\text{Stomach weight} / \text{Body weight}) \times 100$$

A low GaSI often indicates reduced feeding during spawning periods. To assess the general health condition of fish, **Fulton's Condition Factor** (K) was applied using the formula:

$$K = W / L^3$$

Where W = weight (g), L = length (mm)
(Le Cren, 1951; Froese, 2006)

Hepato-somatic index

Hepato-somatic index is an important indicator of fish condition status. In the present, the hepato-somatic index (HSI) was calculated as (liver weight/W gut) *100 following Sokal and Rohlf (1969), where is the gutted weight of fish (g).

3. Reproductive Biology

The reproductive biology of fish was assessed through several parameters. The sex ratio was recorded monthly and statistically tested against the expected 1:1 ratio using the Chi-square test at a significance level of $p < 0.05$ (Snedecor & Cochran, 1967). The spawning season was inferred by integrating observations from changes in the Gonadosomatic Index (GSI), the external and internal morphology of gonads, and ova diameter. These indicators collectively helped determine peak spawning months.

Gonadal maturity staging was performed based on both macroscopic and microscopic features such as colour, distension, and anatomical positioning of the gonads. The classification

followed criteria set by Qasim (1973) and Qayyum & Qasim (1964), allowing the identification of maturity stages across seasons for both sexes.

To quantify reproductive effort, the **Gonadosomatic Index** (GSI) was calculated as:

$$\text{GSI} = (\text{Gonad weight} / \text{Body weight}) \times 100$$

(Hossain & Ohtomi, 2008)

Additionally, ova-diameter measurements were carried out from the anterior, middle, and posterior portions of the ovary using an ocular micrometre, following the method of Hickling and Rutenberg (1936).

Fecundity was estimated by counting eggs from a known weight of subsample and extrapolating to the entire ovary. The formula used was:

$$F = nG/g$$

Where F = fecundity, n = number of eggs in subsample, G = ovary weight, g = subsample weight
(Bagenal, 1978)

Relative fecundity (eggs per gram of body weight) was also assessed and its correlation with body length, body weight, and ovary weight was evaluated to understand reproductive potential.

4. Stock Assessment

The **length-weight relationship** was studied to evaluate the growth pattern using the formula:

$$\text{Log } W = a + b \text{ Log } L$$

Where W = weight (g), L = length (mm), and a, b are constants derived from regression analysis
(Le Cren, 1951)

For growth estimation, **length-frequency** data grouped at 10 mm intervals were analyzed using FiSAT II software (Gayaniilo et al., 2005). The ELEFAN-I method was used to derive growth parameters such as asymptotic length (L_{∞}) and growth coefficient (K). These values were used to calculate the growth performance index (Φ'):

$$\Phi' = 2 \text{ Log } L_{\infty} + \text{Log } K$$

Maximum theoretical age (T_{max}) was estimated by Pauly's formula:

$$T_{\text{max}} = 3/K$$

(Pauly, 1983)

The length at first capture (L_{50}) was estimated from the ascending limb of the length-converted catch curve, indicating the length at which 50% of fish become vulnerable to fishing pressure.

The **length at first maturity** (L_m) was estimated using the formula:

$$L_m = L_\infty \times 2/3$$

(Hoggarth et al., 2006)

Mortality rates were also examined. Natural Mortality (M) was calculated using Pauly's empirical formula (1980):

$$\ln M = -0.0152 - 0.279 \ln L_\infty + 0.6543 \ln K + 0.463 \ln T$$

Where T = mean annual water temperature (°C)

Total Mortality (Z) was estimated using the catch curve method (Jones & van Zalinge, 1981), and Fishing Mortality (F) was derived by:

$$F = Z - M$$

The exploitation rate was expressed in two forms. The **exploitation ratio (E)**:

$$E = F / Z$$

And the **exploitation rate (U)**:

$$U = F / Z \times (1 - e^{-Z})$$

(Gulland et al., 1971; Jaiswar et al., 2003)

Yield and biomass were estimated using the Beverton and Holt (1957) model within FiSAT II to compute yield-per-recruit, biomass-per-recruit, and their relative values under different fishing scenarios.

Finally, Virtual Population Analysis (VPA) was applied using length-structured data to estimate fishing mortality for each size class and to assess the status of the stock under varying fishing pressures.

Conclusion

The methodologies employed in this study offer a comprehensive understanding of fish biology and stock dynamics, which are essential for sustainable fisheries management. Analysing food and feeding habits helps determine dietary preferences and trophic roles, while reproductive biology studies provide insight into breeding patterns and spawning seasons crucial for protecting fish during vulnerable life stages. Stock assessment tools like length-weight relationships, growth models, and mortality estimates help evaluate fish population health and fishing pressure. Using standardized tools such as FiSAT II and established indices ensures consistency, accuracy, and comparability across studies. Together, these approaches allow researchers, policymakers, and fishery managers to make informed decisions regarding conservation, stock enhancement, and responsible harvesting. By integrating biological

knowledge with statistical assessments, we can ensure that fish stocks are not only protected but also optimized for long-term ecological and economic benefits. This holistic understanding supports the core principles of sustainable and science-based fisheries management.

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ECOSYSTEM BASED FISHERIES MANAGEMENT

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Abstract

Inland waters and wetlands are vital ecosystems that support biodiversity, regulate climate, and sustain human livelihoods. Traditional single-species fisheries management in these areas often overlooks ecological complexity, leading to resource depletion and habitat loss. Ecosystem-Based Fisheries Management (EBFM) offers a more holistic approach by integrating ecological relationships, habitat conditions, human activity, and climate impacts. Unlike Maximum Sustainable Yield (MSY)-focused models, EBFM accounts for multispecies dynamics, environmental variability, and socio-economic needs. Rooted in Indigenous knowledge and evolving ecological science, EBFM aligns with global policies such as the Convention on Biological Diversity (CBD). Its adaptive, inclusive framework promotes ecosystem health and resilience in the face of climate change, pollution, and development pressures. For inland waters and wetlands, EBFM ensures sustainable fisheries, safeguards critical habitats, and supports balanced resource use for future generations.

Key words: - Biodiversity, EBFM, Holistic approach, Multispecies dynamics and Sustainable fisheries

Introduction

The aquatic ecosystem is more than just a fish habitat; it is a dynamic, living ecosystem that supports the earth and the people who rely on it. Traditional fisheries management practices, frequently focused on maximizing production from particular species, have proven insufficient to

avert stock collapses, habitat damage, and broader ecosystem imbalances. (Pauly *et al.*, 2002). Ecosystem management has been officially applied in the US since the early 1990s (Grumbine, 1997). Ecosystem-Based Fisheries Management (EBFM) reflects a paradigm shift away from traditional, single-species fisheries management and toward a more integrative and holistic approach that takes into account the whole ecosystem, including ecological relationships, habitat integrity, and fisheries' socioeconomic dimensions.

The limitations of Maximum Sustainable Yield (MSY)-based frameworks, such as their inability to account for multispecies interactions, degradation of habitat, and climate variability, are increasingly recognised as factors that contribute to stock collapses and ecosystem decline (Pauly *et al.*, 2002; Pikitch *et al.*, 2004). In response to these issues, EBFM arose as a management strategy that promotes ecosystem structure, productivity, and resilience while maintaining ecological and social well-being (Garcia & Cochrane, 2005). Traditional fisheries management typically concentrates on a single species or fishing industry (such as groundfish, finfish, etc.) within strict borders (such as exclusive economic zones). Although this method is not consistent among stock assessments, advanced stock evaluations for target species may take into account recruitment success and variability in response to environmental circumstances, predation mortality, or habitat suitability (Essington *et al.*, 2016).

The concept of EBFM is growing. There is no universal definition or consistent application, but it involves hierarchical context, ecological boundaries, ecological integrity, data collecting and monitoring, adaptive leadership, interagency cooperation, shifts in organizational structure, and human integration with nature. Forest ecosystem management focuses on values (Grumbine, 1994), which are also applicable to fisheries. A complete ecosystem-based fisheries management method requires managers to evaluate all relationships between target fish stocks and predators. Topics covered include competition and prey species, weather and climatic effects on fisheries, interactions between fish and their habitats, and fishing's impact on fish populations and habitat (NOAA, 1999). A holistic approach to ocean ecosystem management spans from single-species fisheries management (SSFm) to multi-species and multi-sectoral management (Dolan *et al.*, 2016). There are three types of ecosystem management: ecosystem approach to fisheries management (EAFM or EAF), ecosystem-based fisheries management (EBFM), and ecosystem-based management (EBM). (GRIENT., 2024).

These phrases are sometimes used interchangeably, despite the fact that they refer to different strategies. SSFM stock assessments typically focus on the target stock's biology, including age-based catch history, fishing effort, catchability, and natural mortality to determine the safe biomass level for each fishing season (Dolan *et al.*, 2016; Shertzer *et al.*, 2008).

History and principles of EBFM

In order to achieve sustainable results, Ecosystem-Based Management (EBM) takes a comprehensive approach to managing natural resources, taking into account the entire ecosystem, including people. Although the term "EBM" has become more popular in recent years, Indigenous communities have been using its fundamental ideas for thousands of years. Holt and Talbot's "New Principles for the Conservation of Wild Living Resources" (1978) were the result of a major effort to codify these ideas in the 1970s. Later, these ideas gained recognition on a global scale, particularly impacting debates at the 1978 United Nations Conference on the Law of the Sea (UNCLOS).

Key topics covered in EBFM

Ecosystem management, a response to declining biodiversity and fish yields, is a constantly evolving concept (Grumbine 1994). Grumbine (1994) highlighted 10 key topics in ecological management.

1. Hierarchy
2. Ecological boundaries
3. Ecological integrity
4. Data collection
5. Monitoring
6. Adaptive management
7. Interagency co-operation
8. Organizational change
9. Humans embedded in nature
10. Values

These ten themes are the foundation of a workable definition:

Ecosystem management applies scientific knowledge of ecological interactions to a complicated sociopolitical and values framework. The goal is to maintain the integrity of native ecosystems over time (Grumbine 1994:31).

Policy and Frameworks:

Given the complex interdependencies found in marine ecosystems, Ecosystem-Based Fisheries Management (EBFM) emerged as a response to the shortcomings of conventional single-species management techniques. A growing body of international agreements and national laws have influenced the fundamental frameworks and policies that support EBFM, reflecting the need for sustainable and comprehensive fisheries management.

UNCLOS: With a focus on the preservation and sustainable use of marine biodiversity, the United Nations Convention on the Law of the Sea (UNCLOS, 1982) offers the fundamental legal framework for managing marine resources.

UNFSA (United Nations Fish Stocks Agreement, 1995): By encouraging the sustainable management of straddling and highly migratory fish stocks while taking the precautionary approach and ecosystem factors into account, this agreement supports UNCLOS.

Convention on Biological Diversity (CBD, 1992): Through integrated management techniques, the CBD promotes the sustainable use of biological diversity, including marine resources, and supports the ecosystem approach.

Directive on the Marine Strategy Framework (MSFD, 2008): The MSFD, which was adopted by the EU, incorporates EBFM principles to ensure sustainable use of marine goods and services and aims to achieve Good Environmental Status (GES) of EU marine waters by 2020.

Impact of climate change on EBFM

Changes in seawater and air temperatures, seawater acidity, current strengths, dissolved oxygen levels, primary productivity, nutrient availability, atmospheric patterns, including an increase in the frequency and intensity of storms, an increase in the frequency of marine heatwaves, and other effects are some of the ways that climate change is having an increasingly noticeable impact on marine ecosystems worldwide (IPCC, 2022).

Advantages of EBFM

- EBFM aids in decision-making and enhances our capacity to forecast the consequences of such choices. It is also reasonably priced and has an adaptable design. In particular, EBFM:
- Balances the requirements of society and the environment by facilitating trade-offs between the goals of many stakeholders.

- Improves knowledge of how ecosystems and their constituent parts react to various stresses by forecasting pressures and effects on both individual and combined components of a marine ecosystem. (NOAA fisheries)
- Maintains the stability of ecosystem-level measures, which may result in improved business plans and regulatory stability. It achieves this by:
 - Being economical.
 - Offering a structure for management that is more efficient.
 - Being flexible

EBFM Goals and Fishing's Impact on Ecosystems:

The goal of Ecosystem-Based Fisheries Management (EBFM), a modern, comprehensive approach, is to maintain ecosystem health while promoting balanced human interaction with marine resources. In contrast to conventional mono-species management, EBFM takes into account how species, habitats, and human interactions are interconnected (Pikitch *et al.*, 2004).

Objectives:

Maintaining the Structure and Function of Ecosystems: By preserving habitat quality, food web interactions, and biodiversity, EBFM aims to keep marine ecosystems healthy. This strategy is essential for making sure that ecosystems continue to be robust and fruitful in the face of alterations in the environment or human activity (Pikitch *et al.*, 2004; Link, 2010).

A primary objective of EBFM is to manage fisheries in a manner that promotes livelihoods, food security, and cultural values while safeguarding the ecological systems that enable these services (Long *et al.*, 2015).

Using a Holistic and Adaptive Management Approach: When making decisions, EBFM considers climate variability, environmental changes, and cumulative effects. According to Levin *et al.* (2009), it employs adaptive management techniques that can be modified in response to fresh scientific discoveries.

Engaging Stakeholders and Fostering Interdisciplinary Collaboration: In order to guarantee that all parties have a say in the process, EBFM promotes inclusive governance and cooperation between scientists, legislators, fishermen, and local communities (McLeod & Leslie, 2009).

The Ecological Effect of Fishing on Marine Systems Many of the direct and indirect effects of fishing on marine ecosystems can be detrimental if not controlled appropriately. When fish stocks are overused, it can cause the collapse of important species, so upsetting food chains and

jeopardizing the financial stability of fishing towns. One particularly noteworthy example is the Northwest Atlantic's declining cod population (Pauly *et al.*, 1998)

Habitat Destruction: Some fishing techniques, including bottom trawling, can seriously destroy seafloor habitats including coral reefs, sponge grounds, and seagrass meadows. Along with affecting biodiversity, this destruction lowers ecosystem productivity (Watling & Norse, 1998).

Bycatch and Mortality of Non-Target Species: Non-selective fishing equipment frequently results in the capture of young fish, marine mammals, seabirds, and even endangered species bycatch and mortality of non-target species. This accidental catch might cause population declines and upset the fragile equilibrium in our ecosystems (Hall *et al.*, 2000).

Trophic cascades and food web disruption: Also, major issues are trophic cascades and disturbance of the food web. Eliminating apex predators or important prey species can start a domino effect across food webs that alters species composition and influences ecosystem functioning (Frank *et al.*, 2005).

Disturbance of the carbon cycle: Furthermore, upsetting sediment layers, practices like bottom trawling can release stored carbon and increase greenhouse gas emissions (Sala *et al.*, 2021).

EBFM as a Response to Fishing Impacts: Using Ecosystem-Based Fisheries Management (EBFM) might be a game-changer in addressing fishing's effects. It emphasizes habitat protection, ecological monitoring, and preventative management techniques. Studies conducted in areas including the Baltic Sea and the US Northeast Shelf have indicated that EBFM can support biodiversity, lower bycatch, and help fish supplies recover (Link & Browman, 2014; Gascuel *et al.*, 2016).

EBFM opens the path for the long-term sustainability of marine ecosystems and the communities depending on them by giving ecological integrity top priority, involving stakeholders, and allowing flexible management.

Challenges and Opportunities

Although it provides a thorough and flexible method of managing marine resources, Ecosystem-Based Fisheries Management (EBFM) is not without difficulties. Dealing with the complexity of marine ecosystems themselves is one of the biggest challenges. In contrast to single-species management, EBFM needs to take into consideration environmental variability, interactions between multiple species, and the cumulative effects of human activity (Pikitch *et*

al., 2004). Decision-making is a complex and dynamic process because of this complexity, which frequently results in uncertainty in data and models (Levin *et al.*, 2009).

Significant obstacles are also presented by governance and institutional issues. The coordination needed across sectors, disciplines, and jurisdictions is lacking in many current fisheries management systems, which are still based on species-specific mandates (Long, Charles & Stephenson, 2015). Furthermore, some regions' lack of funding and capacity may cause integrated monitoring system development to be delayed and management measures to be less effective (McLeod & Leslie, 2009).

Notwithstanding these difficulties, EBFM offers significant potential. By combining ecological, social, and economic objectives, it fosters sustainability by assisting in striking a balance between community livelihoods and conservation. More inclusive and flexible governance is promoted by the focus on stakeholder engagement, which enables more regional solutions that take into account both conventional wisdom and empirical data (Link, 2010). Managers are better able to assess trade-offs and predict the long-term effects of their decisions as a result of the expanding availability of spatial data and modelling tools (Gascuel *et al.*, 2016).

Basically, the path to fully integrated EBFM is complicated and takes time, but it also offers a revolutionary chance to guarantee the long-term well-being of marine ecosystems and the communities that rely on them.

Conclusion

A progressive move away from conventional, single-species methods and toward an integrated framework that takes ecological relationships, habitat integrity, and human factors into account is represented by ecosystem-based fisheries management, or EBFM. EBFM provides a potent method to guarantee the sustainability of marine ecosystems in spite of obstacles like data ambiguity, institutional fragmentation, and scarce resources. It facilitates cross-sectoral coordination, adaptive management, and stakeholder participation, allowing for well-informed decision-making that strikes a balance between socioeconomic demands and conservation. EBFM promotes the health of the environment and the community by protecting biodiversity, lowering bycatch, and bolstering resilient fisheries. EBFM has the potential to direct global fisheries toward more equitable and sustainable results as scientific instruments and governance frameworks advance.

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BOUNDARY AND BUND PLANTATION UNDER AGROFORESTRY SYSTEM

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Introduction

Cultivation of tree species in association with agricultural crops is an age old practice but use of term agroforestry to it is quite recent (Tewari 1995). It is collective name for land use systems and technologies where woody perennials are deliberately used on the same management units as agricultural crops and / or animals in some form of spatial arrangement or temporal sequence (Lundgren and Raintree 1982). Now a days this systems of farming has gained the attention of researchers and planners because of its potentials in providing multiple ecosystems services apart from giving livelihood security to the rural poor.

Boundary Plantation

Boundary planting is often referred to as living fences or barrier planting because it involves planting trees along all types of boundaries. These can be the edges of property, agricultural fields, pastures, roads or any other place where fences might be located.

Boundary planting also refers to trees planted for delimitation between two farms for live fencing, buffer between roads and farms, while providing timber, poles, fruits, fuelwood and services like wind breaks and soil erosion control. Under boundary plantation large number of farmers adopted the practice of growing the trees species along their farm boundary to protect their farms. The major species are *Tectona grandis*, *Azadirachta indica*, *Terminalia bellerica*, *Dalbergia sissoo*, *Butea monosperma*, *Acacia catechu*, *Aegle marmelos*, *Tamarindus indica*, *Casuarina equisetifolia*, *Embllica officinalis*, *Acacia arabica*, *Ziziphus mauritiana* *Semecarpus anacardium* are grown on the boundary of the field. The practice of growing multipurpose trees

on the boundary of the field may be due to full fill the local needs of the people at subsistence level.

Bund plantation

Bund plantation is one of the agroforestry systems and most of the farmers adopted this practice growing trees along bunds namely *Tectona grandis*, and *Azadirachta indica*

Name of tree species suitable for bund Plantation and Boundary Plantation

Depending on the agroforestry systems, the common species used in boundary planting systems are *Eucalyptus* spp (Niligiri), *Tectona grandis* (Teak), *Thespesia populnea* (Huvarsi); *Albezia lebbek* (Bage), *Leucaena leucocephala* (Subabul), *Annona squamosa* (Seetaphal), Agarwood, *Gliricidia sepium*, bamboo, *Azadirachta indica* both in land demarcation, road stabilization and on-farm while in this system, *Eucalyptus* is exclusively used for road stabilization and rarely in land demarcation because it is highly competitive with associated crops.

The contour hedgerows are managed through pruning, thinning on the roads and in the demarcation. The products of management are used according to the decision of farmers, particularly for trees planted for demarcation. The branches pruned are used for example for firewood, and staking if they are strong enough to support beans or tomatoes. The use of leaves is not well established but many times are abandoned in the plantation. The trees planted for road stabilization are not used by the general population because it belongs to government. The management of those trees, in terms of thinning and pruning, is done by government. Once mature, trees are used for charcoal (*Eucalyptus* spp), timber and firewood (*Grevillea* and *Markhamia*). When young, the plants are also protected against damage from animals and human beings. The weeding is only done around young trees. Watering trees is not a common practice because the trees are accommodated with residual humidity in the soil. However, in the nursery, seedlings are watered.

Block plantation In many of places in Bangladesh, monoculture and block plantation of agar tree are very common (Rahman et al., 2015). But, there is hardly any information available regarding the block plantation (monoculture) in Northeast of India, even though few block plantations are seen to exist in the state like Tripura.

Boundary plantation Ha and Nghi (2011) reported that, agarwood tree is suitable for growing on field boundaries and even on borders of gardens, school compounds, office compounds, parks

and residential sites. Besides, agarwood tree has been successfully grown for strip planting along banks of ponds, tanks, canals and roads. In hilly areas / tillas, it can be planted on poor soils on hill slopes and tilla tops which can help in reducing soil erosion and land sliding (Shinde et al., 2019) caused by rushing water during rainy season (Ha and Nghi, 2011). Similar type of plantation can also be followed in this region.

Products and services

The major products provided in boundary trees planting are: fuel (firewood and charcoal), construction (timber and poles), bean stakes (branches) and indirect utilities for road stabilization, soil erosion control and other environmental services (including windbreak, shade, micro and macro climate regulation) and resilience to climate change.

Products

Fire wood: For many households, wood fuel is the primary utility derived from specific tree species they planted on boundary tree planting. Households in rural areas rely heavily on fuelwood for their energy needs for cooking meals. Note the objective of boundary trees planting is not to primarily satisfy firewood or charcoal needs, but is mainly used for land demarcation and road stabilization.

Timber/poles for construction: In boundary tree planting, trees like alnus, Grevillea, and eucalyptus can be used for timber when trees are mature.

Services

Soil erosion, windbreaks and shade: Boundary trees planting are essentially established for road stabilization and land delimitation. Besides these major services, they contribute to soil erosion control, wind breaks, shade and resilience to climate change.

Carbon sequestration: The boundary trees planting contribute to carbon sequestration through immobilization of carbon in the wood and reduce siltation for river or lakes in down stream

Products and Services	High	Medium	Low
Products			
Poles		Y	
Firewood		Y	
Timber		Y	

Services			
N ₂ Fixation and recycling		Y	
C sequestration		Y	
Soil erosion Control	Y		
Biodiversity conservation		Y	

Preferable characteristics of tree species to be promoted for Bund Plantation/ Boundary Plantation

The characteristics of boundary planting trees should be straight, noncompetitive, to have capacity to control soil erosion, improving soil fertility by leaf falling. Extraction of nutrients and water should be less so that the crop grown nearby should give better production.

Boundary plantation is prominent feature of Indian agroforestry system as it very popular among the farmers due its less interference, ease in mechanization and demarcation of field boundaries. Plantation of *Eucalyptus* spp on the boundary and its suitable combination play a vital role in enhancement of better yield productivity, soil nutrient status and microbial population dynamics which plays a major role in nutrient cycling to maintain ecosystem. Due to shading effect and strong root system of *Eucalyptus*, which compete for moisture and nutrient with crops resulting grain yield near the tree lines was comparatively low. *Eucalyptus* is a cropland agroforestry tree species planted along with various annual crops like paddy, wheat, and cereals and other cash crops in farmers' lands either in scattered or in bund. *Eucalyptus globulus* trees are unpalatable to goats, sheep and cattle. Thus they have a distinct advantage as boundary planting in recommended inter-row spacing and are aligned east–west or north-south direction. In this environment, eucalypt boundaries produce a harvestable tree crop within four to five years after planting.

Management of tree component planted in Bund Plantation & Boundary Plantation

They are managed through pruning, thinning on the roads and in the demarcation. The products of management are used according to the decision of farmers, particularly for trees planted for demarcation. The branches pruned are used for example for firewood, and staking if they are strong enough to support beans or tomatoes. The use of leaves is not well established but

many times are abandoned in the plantation. When young, the plants are also protected against damage from animals and human beings. The weeding is only done around young trees. Watering trees is not a common practice because the trees are accommodated with residual humidity in the soil. Other practices are not generally adopted.

Economic returns

Effect of Bund Plantation & Boundary Plantation on crop yield

The outcome of yield is depends upon tree spacing, density, type and nature of existing bund plantation and their shading effects.. The yield of crops increased with the increase in distance from the boundary.



Bamboo in field boundary



Medicinal shrubs (Pochotia) as live fencing surrounding vegetables/ field crops



Arecanut as boundary plantation surrounding mixed vegetables



Banana plantation at pond dyke

Trees under agroforestry besides providing the tree products, improves soil productivity through ecological and physico-chemical changes. Owing to the fast growth, deciduous nature, marketing acceptability and successful intercropping, poplar cultivation has become popular among the farmers as a viable alternative to wheat-paddy rotation in north-western states of

India. Poplar being a deciduous tree enters in dormancy during winter, therefore suited well to companion crop for ensuring food production and also enhance economic returns to the growers. This species has been grown by farmers as boundary or block plantation, which This improves the physico-chemical properties of soil through addition of organic matter in the soil and provides alternate sources of income and employment to the rural poor. Leaf-fall at sowing poses physical barrier to seed germination and may affect the availability of nutrients/light to developing seedlings but addition of leaves changes the C: N ratio of the soil, which also influence the crop growth. Poplar being sensitive to water logging is unsuitable under rice based cropping system, but boundary plantation of poplar might be an option to continue traditional rotation of rice-wheat for the farmers who seem reluctant to leave the rotation because of assured market/minimum support price of the crops.

Crop yield

The distance from the boundary plantations have effect on crop growth. As the distance increases the growth also seems to be more. The visual observations made for rice crop growing with boundary plantation showed that the growth of the crop plants were poor as we moved towards the tree line in each direction from the centre of the field. The establishment of crop was poor near the tree line.

Distance of minimum 2.5 to 3 meter distance are necessary and plantation should be done in such a way that sunlight should not be hampered

- would the planting of trees shade the crops and prevent the crops from growing well ?
- would the planted saplings be grazed while these were still young, since cattle freely grazed on farmlands in the non-agricultural months ?
- would the roots of these trees intrude into the fields and disturb the growth of preferred crops ?
- would the effort of planting and caring for the trees be worth the investment ?

The recommended technique included

- establishing trees on bunds by transplanting nursery-grown saplings,
- regularly lopping off the trees of any height beyond 6 ft., and
- shearing off all the leaves from the entire tree well before the crop planting season each year.



- This eliminated the threat of crop-shading and ensured that the leaves were incorporated into the soil in time for planting of crops. Cassia Siamea was chosen as the main species to be planted on the bunds. Even though it did not have merits of high-quality leaf matter producer, it was not bad either as it was, by and large, non-browsable. Further, it was a nitrogen-fixating tree. Other species like Glyricidia were also planted in response to availability and farmers' preferences.
- Live fencing with woody perennials is need of our species suitable for the purpose need to be exempted from felling restrictions under state Agroforestry Policy

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ARTIFICIAL NEURAL NETWORK AND ITS APPLICATIONS IN AGRICULTURE

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Introduction

In the era of modern agriculture high productivity and outstanding produce quality are becoming more and more important especially in crop production. Artificial intelligence (AI) and other cutting-edge technologies have emerged as essential instruments for optimising agricultural operations in order to achieve these expectations. Innovations like IoT-based sensors, remote sensing, and automated systems, which allow for real-time monitoring of soil, crops, and environmental conditions, have made smart farming methods possible due to the rapid rise of information and communication technologies. These developments make it easier to make smarter decisions, use resources more effectively, identify diseases and pests early, and apply inputs precisely all of which contribute to increased sustainability and profitability. Artificial Neural Networks (ANNs) are essential in this framework because they have strong data analysis and forecasting capabilities that can simulate intricate agricultural systems and support intelligent farm management.

What is Artificial Neural Network:

Artificial Neural Network is one of the major and important components of Machine learning and Artificial Intelligence. ANN has three layers namely input, hidden and out put layer. Ann is the digitized version of human brain and where the neurons are connected to each other likewise in ANN input and output layers are connected through weighted links through the hidden layer. Any type of either image or numerical data is fed to the input layer and all the

calculations for finding hidden patterns performed in hidden layer. The information passed from the hidden layer is subjected to activation function helps in assigning the weights to the data and some series of transformations done and final result passes to the output layer.

How Artificial Neural Network works?

The training process in ANN occurs in two different ways:

1.Feed forward Propagation: In this data fed forward from the input layer to the output layer through hidden layer. Hidden layer receives weighted input from the input layer and calculates weighted sum and applies an activation function to produce the result. This process continues until the output layer generates the network predictions.

2.Feed Backward Propagation: After the feedforward prediction, backpropagation computes the error (or loss) by comparing the predicted value with the actual value. Backpropagation determines the gradient of the loss function with respect to each network weight using the chain rule of calculus. In order to modify the weights in a way that minimises the error, these gradients lead the optimisation process (often gradient descent).

This iterative process of prediction, error calculation, and weight adjustment is repeated, with the network learning to make more accurate predictions over time.

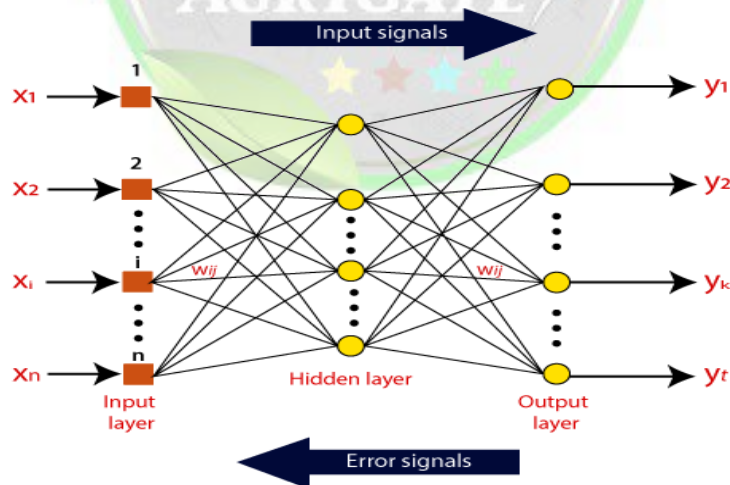


Fig 1. ANN model structure

(Source: <https://ai.plainenglish.io/artificial-neural-network-ann-edec89ce4daa>)

Applications of ANN in Agriculture:

Artificial neural networks are getting demand day by day in modern agriculture due to their ability to handle complex and nonlinear relationships in datasets. In soil management, ANN is

used for prediction of soil nutrient status, soil temperature, moisture levels, classify soils based on various properties. But to get accurate predictions huge amount of data is required. Where as in crop management, ANN used for prediction of crop yields by analyzing the factors like weather, soil conditions and farming practices. They also model the response of crops to different nutrients, fertilizers and crop protection chemicals. pest and diseases prediction. ANNs use information about the environment and plant health to help predict pest and disease outbreaks. These projections reduce crop losses and promote early interventions. However, the availability of high-quality data is crucial to the performance of ANN models. In agriculture, well-trained models can greatly enhance decision-making.

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GENOME EDITING AND ITS SIGNIFICANCE

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Abstract

Genome editing is a powerful and rapidly advancing biotechnology that allows precise and targeted modifications in the DNA of living organisms. Among various tools, CRISPR/Cas9 has emerged as the most widely used due to its simplicity, efficiency, and affordability. This review highlights the working mechanism of CRISPR/Cas9, detailing steps from target site selection to plant regeneration. It also explores key agricultural applications including disease resistance, yield enhancement, abiotic stress tolerance, quality improvement, and herbicide resistance. Genome editing holds immense promise for sustainable agriculture by enabling the development of improved crop varieties without introducing foreign DNA, offering a significant advantage over traditional breeding methods.

Keywords

Genome editing; CRISPR/Cas9; Disease resistance; Quality improvement; Abiotic stress

1. Introduction

Genome editing is a recent and rapidly evolving technology enables targeted modification in DNA of an organism. This technique allows precise changes at specific genomic sites that prove its superiority over other traditional breeding that depends on random mutations or hybridization. Basic tools of genome editing involve CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats CRISPR associated protein 9), TALENs (Transcription Activator-Like Effector Nucleases), and ZFNs (Zinc Finger Nucleases). These tools has revolutionized genetics, biotechnology, medicine, and last but not least; 'Agriculture'. This

review summarizes the working principle of genome editing specially CRISPR Cas 9 with its applications in agriculture.

2. Working principle:

CRISPR Cas 9 endonuclease is the most transformative genome editing tool. Among all the genome editing tool CRISPR being the most widely adopted due to its simplicity, efficiency, and cost-effectiveness. Derived from a bacterial immune system, CRISPR/Cas9 uses a guide RNA (gRNA) to direct Cas9 to a specific genomic site. Steps involved in genome editing include:

- A. **Target site selection:** Researchers identify a specific gene or DNA sequence to edit based on the trait of interest (e.g., disease resistance, drought tolerance).
- B. **Designing and editing tool:** CRISPR/Cas9 uses a synthetic guide RNA (gRNA) that matches the DNA target. Cas9 is a **nuclease enzyme** that cuts DNA at the site directed by the gRNA.
- C. **Delivery into plant cell:** The gene-editing tool (e.g., CRISPR-Cas9 system) is introduced into plant cells using methods like: *Agrobacterium tumefaciens*-mediated transformation (commonly used in dicots); Biolistic (gene gun) transformation (useful for monocots like maize); Protoplast transfection (temporary delivery into plant cells without a cell wall).
- D. **DNA cleavage:** The Cas9 protein, guided by the gRNA, binds to the target DNA and makes a double-stranded break (DSB) at the specific site.
- E. **DNA repair by the cell:** The plant's natural DNA repair mechanisms fix the DSB using two main pathways:
 - a) **Non-Homologous End Joining (NHEJ);** An error-prone repair pathway that Causes small insertions or deletions (indels) that can knock out a gene. It is Used to disable undesirable genes (e.g., disease susceptibility genes).
 - b) **Homology-Directed Repair (HDR);** An accurate repair using a template DNA. It used to insert or replace genes with desired sequences. It Less efficient in plants but important for precise trait improvement.
- F. **Regeneration into whole plants:** The edited cells are regenerated into whole plants using tissue culture techniques. Plants are then screened for successful edits using molecular techniques (PCR, sequencing).

3. Applications of Genome Editing in Agriculture: Genome editing offers precise, fast, and cost-effective ways to improve crops including:

- A. Disease Resistance:** Genome editing allows precise disruption or modification of susceptibility (S) genes, enabling resistance to pathogens. Example: Rice: Knockout of the OsSWEET gene confers resistance to bacterial blight (Zhang and Bai et al., 2022); Wheat: Editing of TaMLO gene provides resistance to powdery mildew; Tomato: CRISPR was used to develop resistance to tomato yellow leaf curl virus.
- B. Yield and Productivity Enhancement:** Targeted gene edits can influence plant architecture, flowering time, or grain size for yield optimization. Example: Rice Editing of OsSPL14 gene improves plant architecture and increases yield in Rice (Li et al., 2023) and CRISPR-based modification of ARGOS8 improves drought tolerance and yield under stress conditions in Maize.
- C. Abiotic Stress Tolerance:** Genome editing helps develop crops that can withstand drought, salinity, heat, and cold stress. Example; Edited GmFT2a gene confers early flowering and better drought escape in Soybean; Knockout of SlMAPK3 or DREB genes enhances drought and salt tolerance in Tomato and Arabidopsi; salinity tolerance in wheat (Zhang et al., 2022)
- D. Quality Improvement:** Nutritional content, shelf life, and taste can be modified precisely without introducing foreign DNA. Example: CRISPR used to develop varieties with enhanced lycopene content and extended shelf life in Tomato (Kakimoto et al., 2023); reduced acrylamide production via editing asparagine synthetase genes in Potato; Low-gluten wheat for celiac-friendly consumption by disrupting gliadin genes.
- E. Herbicide Tolerance:** Genome editing can introduce herbicide resistance by modifying endogenous target sites. Example: editing of ALS gene confers tolerance to sulfonylurea herbicides in Rice; CRISPR used to develop lines tolerant to glyphosate and glufosinate in Canola.

4. Ethical, Regulatory, and Social Issues:

Regulatory frameworks regarding genome edited crops is variable among countries. Some countries treat genome-edited crops as GMOs; others exempt them if no foreign DNA is inserted. India is drafting guidelines to regulate genome-edited crops separately from GMOs (DBT India, 2022). The EU is reconsidering its strict GMO stance due to the precision of CRISPR techniques.

Conclusion

Genome editing stands at the forefront of a new genetic revolution. Its applications in sustainable agriculture are transformative. Specifically; CRISPR/Cas9, represents a transformative leap in agricultural biotechnology, enabling precise and efficient genetic improvements in crops. Its ability to modify specific genes responsible for disease susceptibility, stress response, and yield traits makes it a vital tool for developing climate-resilient and nutritionally enhanced crops. As regulatory frameworks evolve and technical challenges such as delivery and efficiency are refined, genome editing is poised to play a central role in ensuring food security and sustainability in the face of global environmental and population pressures. Continued research, public awareness, and policy support will be crucial for the responsible and widespread adoption of this technology in agriculture.

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IOT ON SOIL HEALTH MANAGEMENT

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Abstract

The integration of the Internet of Things (IoT) into agriculture is adapting soil health control by means of enabling real-time records series and automation. Through a network of clever sensors, farmers can now screen essential soil parameters such as moisture, temperature, pH, and nutrient levels with excessive precision. This actual-time records lets in for information-driven decisions that considerably enhance crop productiveness even as selling sustainability. IoT technology empower precision agriculture by way of optimizing irrigation schedules, fertilization practices, and crop making plans, resulting in healthier plants, better yields, and more green use of assets including water and fertilizers. These improvements also make a contribution to environmental safety by using reducing overuse of inputs and minimizing runoff and soil degradation. Despite demanding situations consisting of restricted technical information among a few farmers, the growing availability of user-pleasant systems and mobile applications makes IoT solutions reachable, scalable, and fee-powerful, even in faraway or resource-restricted regions. By bridging the gap between traditional farming and cutting-edge era, IoT marks a pivotal shift toward smarter, greater resilient, and environmentally accountable agricultural structures.

Introduction

Imagine a farm in which selections are made no longer with the aid of guesswork, however through actual-time statistics sent from the soil itself. Where the land talks to farmers through their smartphones. This isn't always an imaginative and prescient of the remote destiny - it's already going on nowadays, thanks to the Internet of Things (IoT). In agriculture, where every inch of land topics and each crop cycle counts, IoT is transforming conventional practices into a brand new era of “Smart Farming.” Soil health lies on the core of agricultural achievement. Healthy soil promotes higher crop yields, extra efficient water use, and sustainable land control. IoT-based soil monitoring technologies now allow farmers to degree the entirety from moisture and pH to nutrient content and solar radiation - all from a far flung tool. This revolution is turning reactive farming into **proactive** management, boosting efficiency, reducing waste, and protecting the surroundings.

Understanding IoT in Agriculture

IoT refers to a machine of interconnected devices that collect, share, and analyse data by statistically. In farming, IoT gadgets - inclusive of sensors, controllers, and data loggers - are used to display numerous environmental parameters. These sensors gather statistics on soil temperature, moisture, pH, and nutrient levels (such as nitrogen, phosphorus, and potassium). The gathered facts is then transmitted wirelessly to a cloud-based platform, where it's visualized on dashboards or analyzed via software applications.

Type of setup provides farmers with the ability to

- Monitor soil and weather conditions in real time
- Automate irrigation systems
- Predict pest and diseases outbreaks or nutrient deficiencies
- Optimize planting, fertilizing, and harvesting schedules

Collectively, these capabilities enable precision agriculture, where resources are applied exactly where and when they're needed.

The core of smart farming: soil Health

Soil is a complex, living ecosystem that helps plant growth and nutrient cycling. Soil health determines a crop's ability to grow, resist pests, and intake of water and nutrients efficiently. Degraded soil can cause reduced productiveness, higher charges, and more reliance on chemical inputs.

Monitoring soil health helps farmers

- Maintain balance nutrients
- Prevent over-fertilization
- Enhance water retention
- Reduce erosion and compaction
- Promote biodiversity in the soil micro-biome

By combining these principle with IoT tools, farmers and keep a real-time pulse on their soil's condition and make timely decisions to preserve and enhance its health.

What do IoT Sensors Measure?

IoT - enable Smart Agriculture System integrate a variety of sensors designed for different aspects of soil monitoring. Here are some of the most important sensors.

1. Soil Moisture: Moisture sensors often buried at multiple depths perceive how much water is available in the soil. This is crucial because:

- Water is essential for photosynthesis
- Soil moisture influences nutrient uptake
- Over or under watering can severely affect crop yield

These sensors help automate irrigation systems, ensuring crops get just the right amount of water.

2. Soil Temperature: Soil temperature will effects on root growth, respiration, decomposition, and nutrient mineralisation in the soil. The most precise measurement on soil temperature assists farmers to decide the right time to plant and cultivate crops to make certain better productivity. Temperature sensors or IoT sensors that use infrared (IR) technology may be strategically placed underneath the floor to offer farmers with actual-time updates on soil temperature

3. Nutrient Levels (NPK): Advanced NPK sensors measure the levels of Nitrogen (N), Phosphorus (P), and Potassium (K) 3 vital elements for plant boom. These sensors can also screen pH, and EC. With IoT sensors and related gadgets, farmers can locate dietary deficiency of soil, and for that reason, decide they want to use the right kind of fertilizers to improve crop productiveness without affecting soil fertility.

4. Solar Radiation and Weather Conditions: IoT systems integrate with weather stations to track:

- Rainfall and Humidity

- Wind speed and direction
- Atmospheric pressure
- Solar radiation

5. Additional Parameters: IoT system can also monitor:

- Soil oxygen content
- Leaf wetness
- Trunk and stem diameter
- Soil water potential
- Vapour pressure



How it all works: From Sensors to Smartphone

Here's a simplified breakdown of the typical IoT system in smart farming:

1. Sensing: Sensors collect data from the soil and environment.
2. Transmission: The data is sent wirelessly using technologies such as LoRaWAN, WiFi, 5G, or even satellite.
3. Cloud Processing: Data is stored and processed in the cloud.
4. Visualization: Information is displayed on dashboards via smartphones or computers.
5. Decision Making: Farmers receive alerts or recommendations to take action—or systems can automatically adjust conditions.

Low power consumption and solar-powered sensors make these systems suitable even for off-grid locations.

Benefits of IoT in Soil Health Management

- **24/7 Real-Time Monitoring**

IoT sensors embedded in soil allow farmers to monitor critical parameters - such as moisture and temperature round the clock, without manual checks.

- **Remote and Cost-Effective Management**

Agritech devices enable remote soil monitoring, reducing the need for frequent field visits and lowering long-term operational costs.

- **Smart Water Usage**

With accurate moisture data, IoT helps in optimizing irrigation schedules, preventing overwatering or under watering, and conserving groundwater resources.

- **Healthier Crops, Better Yields**

By avoiding irrigation errors, farmers can prevent poor plant health and ensure better crop growth and productivity.

- **Automated and Accurate Data Collection**

IoT solutions eliminate the guesswork involved in traditional soil testing by providing timely, precise, and automated data.

- **Improved Decision-Making**

With comprehensive insights into soil health, farm managers can take proactive measures to maintain fertility and boost crop success.

- **Better Crop Planning**

IoT aids in selecting the best-suited crops based on real-time conditions such as temperature, moisture, weather trends, and nutrient levels.

- **Time and Resource Savings**

Automated processes help save valuable time and reduce resource wastage, improving overall farm efficiency and profitability.

- **Expert Guidance Still needed**

Despite the benefits, many farmers lack technical or soil science knowledge—making expert support essential for interpreting data and making informed decisions.

Real – World Impact

Across the globe, pilot programs and commercial farms using IoT soil monitoring systems have shown:

- 20–30% savings in water usage through smart irrigation.
- Improved yield consistency due to timely interventions based on real-time data.
- Reduced use of fertilizers, leading to cost savings and lower environmental impact.

Smallholder farmers in developing regions can now make data-backed decisions using mobile apps and cloud-based dashboards

IoT in Remote and Challenging Environments

- One major advantage of IoT solutions is the ability to work in rural or isolated areas. Sensors with LoRaWAN can transmit data up to 15 km, and satellite communication can bridge the rest.
- This makes it possible for farmers in mountainous, desert, or forested regions to monitor soil health with the same sophistication as those in high-tech agricultural hubs.
- One major advantage of IoT solutions is the ability to work in rural or isolated areas. Sensors with LoRaWAN can transmit data up to 15 km, and satellite communication can bridge the rest.
- This makes it possible for farmers in mountainous, desert, or forested regions to monitor soil health with the same sophistication as those in high-tech agricultural hubs.

Beyond Monitoring: Automation and Control

IoT doesn't stop at data collection. It also enables automation. For example:

- If soil moisture falls below a threshold, the system can activate irrigation pumps.
- When NPK levels exceed safe limits, alerts can notify operators.
- Weather predictions can trigger preventive actions against pests or diseases.

These automated responses reduce the burden on labour and increase operational efficiency.

Conclusion

The integration of IoT into soil health management represents a transformative shift in agriculture. It empowers farmers with actual-time insights, predictive analytics, and automated systems that collectively sell extra sustainable, efficient, and resilient farming practices. By embracing IoT, we're now not just making farms extra green, we're preserving soil health for



future generations, lowering environmental impact, and improving food security around the world. Whether growing soybeans within the Midwest, apples in the Himalayas, or hemp in California, smart soil tracking system are unexpectedly becoming an essential device. As technology continues to evolve and become more affordable, smart farming will no longer be a luxury, however a necessity for each person extreme about sustainable agriculture.



THE GREAT PACIFIC GARBAGE PATCH: “A FLOATING CRISIS OF PLASTIC POLLUTION”

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Abstract

The Great Pacific Garbage Patch (GPGP) is the largest accumulation of marine plastic debris, posing serious threats to marine life, ecosystems, and potentially human health. Comprised mainly of microplastics and larger plastic fragments, the GPGP results from decades of unchecked plastic production and poor waste management. It harms marine species through ingestion, entanglement, and the spread of toxins and invasive microbes. While initiatives like The Ocean Cleanup aim to reduce its size, experts stress that preventing plastic from entering the ocean is the most effective solution. Addressing this crisis requires global cooperation, public awareness, and a shift toward sustainable plastic use.

Introduction

Plastic debris can harm marine life in various ways, including the release of toxic chemicals, entanglement of animals, choking and starvation due to ingestion, and the spread of non-native and potentially harmful organisms (Egger et al., 2020). The North Pacific Ocean contains an estimated 80,000 tonnes of floating debris, commonly referred to as the Great Pacific Garbage Patch (GPGP). Among the five major oceanic garbage patches worldwide, the GPGP is the largest (Greenly et al., 2021).

The Great Pacific Garbage Patch, also called the Pacific trash vortex, stretches from the west coast of North America to Japan. It is made up of two main regions: the Western Garbage Patch near Japan and the Eastern Garbage Patch situated between Hawaii and California.

These swirling zones of debris are connected by the North Pacific Subtropical Convergence Zone, located a few hundred kilometres north of Hawaii. This zone, where warm waters from the South Pacific meet cooler Arctic waters, functions like a highway, transporting debris between the two patches (Source: National geographic).

In Long Beach, California, a small marine science group is working hard to protect our oceans from plastic pollution. It was started by Captain Charles Moore, the man who first brought attention to the Great Pacific Garbage Patch back in the 1990s. Since then, the team has been sharing important facts about ocean plastic and why it matters. “We’re trying to learn things that really make a difference,” says Captain Moore. “And they want to show that everyday people—like us—can help scientists understand what’s happening in the world” (De-wolff., 2014).

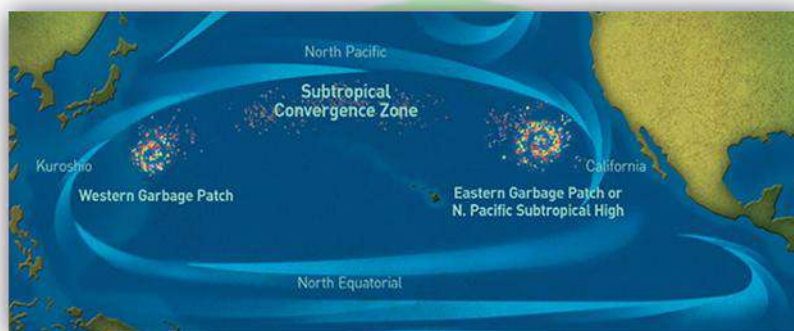


Fig 1: Great pacific garbage patch formation (Source: NOAA)

The Ocean is Speaking—Are We Listening?

The Great Pacific Garbage Patch represents a profound environmental crisis reflecting decades of excessive plastic production and inadequate waste management. The oceans now hold more than 5 trillion plastic particles, weighing over 250,000 tons, disrupting marine ecosystems on a massive scale (Eriksen *et al.*, 2014). Marine animals from the smallest plankton to large mammals ingest plastics or become entangled, often resulting in injury, reproductive failure, or death, which threatens the balance of marine biodiversity and the health of global food webs (Wright *et al.*, 2013).

This plastic pollution also acts as a carrier for toxic substances such as persistent organic pollutants, which accumulate in marine organisms and can ultimately affect human health through seafood consumption (Jambeck *et al.*, 2015). The degradation of plastics into microplastics further complicates the issue, as these tiny particles are nearly impossible to remove and widely distributed throughout the ocean, entering the deepest trenches and polar

regions (UNEP, 2021).

While various cleanup technologies are under development, they face significant limitations due to the vastness of the ocean and the continual input of new plastic waste. Therefore, experts widely agree that prevention of plastic pollution at its source is the most effective and sustainable solution. This requires a fundamental shift in how societies produce, use, and dispose of plastic materials, embracing a circular economy that prioritizes waste reduction, reuse, and recycling (Moore, 2011).

At the policy level, stronger international cooperation and legally binding agreements are crucial to regulate plastic production, improve global waste management infrastructure, and hold industries accountable for pollution (UNEP, 2021). Public awareness and education are equally important to drive behavioral change, encouraging individuals to reduce single-use plastics and support sustainable alternatives.

The ocean's plight is a call for immediate and coordinated action. Without significant efforts to curb plastic pollution at its source, the consequences for marine ecosystems and humanity will only intensify. Listening to this warning means committing to systemic changes before the damage becomes irreversible.

The connection between microplastics and GPGP

The Great Pacific Garbage Patch (GPGP) is one of the most concentrated zones of marine debris, primarily made up of plastics (Lebreton *et al.*, 2018). A significant portion of this is microplastics—tiny plastic fragments under 5 mm—originating from the breakdown of larger plastics or direct sources like cosmetics and synthetic fabrics (Andrady, 2011; Browne *et al.*, 2011). Driven by the North Pacific Gyre, the GPGP continually collects and retains these pollutants, acting both as a reservoir and a source of microplastic pollution (Eriksen *et al.*, 2014; Cózar *et al.*, 2014).

These microplastics pose serious risks to marine life through ingestion and the release of toxins (Wright *et al.*, 2013; Cole *et al.*, 2011). While their movement and degradation processes are still being studied, microplastics can sink or be transported through the water column by marine organisms (Koelmans *et al.*, 2017). They also host microbial communities that may spread harmful species (Zettler *et al.*, 2013).

Though remote, the GPGP's microplastic pollution can impact global marine ecosystems due to oceanic transport (van-Sebille *et al.*, 2015). Understanding this connection is crucial for

addressing the broader issue of plastic pollution and developing effective solutions.

Impact of this patch

The Great Pacific Garbage Patch (GPGP) significantly impacts marine ecosystems, biodiversity, and potentially human health. It acts as a persistent zone of plastic accumulation in the North Pacific Ocean, mainly consisting of microplastics and larger plastic debris (Lebreton *et al.*, 2018). One of the primary ecological concerns is the ingestion of plastic by marine organisms. Many species, including fish, seabirds, and turtles, mistake plastic for food, which can lead to malnutrition, internal injury, and death (Wright, Thompson and Galloway, 2013).

Microplastics in the GPGP also act as carriers of toxic pollutants such as PCBs and heavy metals, which adsorb onto the plastic surface and may enter the marine food chain (Rochman *et al.*, 2013). Furthermore, plastics provide surfaces for microbial colonization—forming the so-called "plastisphere"—which can spread invasive or harmful microorganisms across ocean regions (Zettler, Mincer and Amaral-Zettler, 2013).

The GPGP also disrupts oceanic processes. Floating plastic debris can alter sunlight penetration and local temperatures, potentially affecting plankton productivity and nutrient cycling (Andrady, 2011). Though remote, the GPGP has global implications due to ocean currents that transport plastic and associated contaminants across marine environments (van-Sebille *et al.*, 2015).

Recent initiatives

Several innovative approaches have been proposed to tackle the Great Pacific Garbage Patch. Among them was a 2012 concept of an underwater skyscraper designed to collect plastics as ocean currents flowed through it. A more practical and widely recognized effort is that of *The Ocean Cleanup*, a nonprofit organization based in the Netherlands. After years of development, the group launched its first cleanup system in 2018—a 600-meter-long floating barrier with a submerged skirt intended to concentrate and trap plastic debris while allowing marine life to pass beneath it (Source: The Ocean Cleanup, 2021).

In 2021, a larger prototype system named *Jenny* was deployed. Over twelve weeks, it successfully removed around 20,000 pounds of plastic, demonstrating the potential for scaled operations. The Ocean Cleanup aims to reduce the size of the patch by up to 90% by 2040 through a fleet of such systems. They have also developed solar-powered *Interceptors* to capture plastic in rivers before it enters the ocean.

Despite these advancements, experts emphasize that large-scale ocean cleanup remains extremely challenging due to technical, economic, and political barriers. Many scientists argue that preventing plastic from entering marine environments in the first place is the most effective long-term solution (Moore, 2011).

“The ocean does not belong to us; we belong to the ocean. Destroying it with plastic waste is destroying ourselves.”

Captain Charles Moore, Oceanographer who discovered the Great Pacific Garbage Patch

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ADVANCING SUSTAINABLE SOIL HEALTH AND CLIMATE RESILIENCE THROUGH BIOCHAR INNOVATIONS AT UAS, BANGALORE

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Introduction

Soil degradation is a major global concern affecting nearly 33% of the Earth's land area (FAO, 2021). In India alone, around 120.72 million hectares are impacted by various forms of land degradation (NBSS&LUP, 2015). The Ministry of Agriculture & Farmers Welfare (2020) reports that about 30% of the country's total geographical area is degraded, primarily due to soil erosion, which accounts for 71% of this degradation. A particularly pressing issue is the decline in soil organic carbon (SOC), with Indian soils averaging 0.3–0.5% organic carbon — well below the optimal 0.8–1.0% necessary for sustainable crop production (ICAR, 2021). Conventional agricultural practices such as excessive tillage, imbalance fertilizer use and mono-cropping have led to nutrient depletion and soil erosion, further reducing SOC. This decline adversely affects soil fertility, water retention, microbial activity, and long-term agricultural productivity.

The urgent need to restore soil health has driven interest in biochar as a sustainable amendment. Research suggests that biochar application can increase SOC by 15–30% within 2–3 years of consistent use (Jeffery *et al.*, 2017). On-farm trials in India have demonstrated SOC improvements of 0.2–0.4% with biochar applications at 5–10 t/ha over a two-year period (UAS Bangalore, 2022; CAFRI, 2021). Biochar not only improves soil fertility and structure but also contributes significantly to carbon sequestration, greenhouse gas mitigation, and resilience to climate variability.

Biochar Production and Characteristics: Biochar is produced by heating organic biomass (e.g., crop residues, wood chips, animal manure) in a low-oxygen environment, yielding a stable, carbon-rich material. Key production methods include:

- Slow pyrolysis (300-500°C): Higher biochar yields.
- Fast pyrolysis (500-700°C): Produces more bio-oil with less biochar.
- Gasification (>700°C): Prioritizes syngas, with biochar as a by-product.

Advanced techniques like microwave-assisted pyrolysis, hydrothermal carbonization, and torrefaction offer improved control over biochar properties.

Typical biochar characteristics:

- pH: 6.5–9.0
- Surface area: 10–400 m²/g (up to 800 m²/g for activated biochar)
- Cation exchange capacity: 20–50 cmol/kg (can reach 100 cmol/kg after modification)
- Carbon content: 50–90%

Benefits of Biochar as a Soil Amendment:

1. Biochar enhances nutrient retention and increases soil cation exchange capacity, contributing to improved soil fertility and crop productivity.
2. A global meta-analysis (Jeffery et al., 2017) covering 109 studies reported an average 11% increase in crop yields with biochar application.
3. Functionalized biochar enriched with nitrogen and phosphorus has shown 20–30% improvements in nutrient-use efficiency in cereal crops.
4. It improves soil physical properties by increasing aeration, water retention, and reducing bulk density.
5. Liu et al. (2013) observed a 15% rise in water holding capacity in sandy soils amended with biochar.
6. In arid regions, blending biochar with hydrogels improved water-use efficiency by 25–35%.
7. The porous structure of biochar supports beneficial microbial populations, promoting soil biological activity.
8. Singh et al. (2019) documented a 20–30% increase in microbial biomass carbon with biochar application at 10 t/ha.

9. Biochar pores harbor nitrogen-fixing and phosphorus-solubilizing bacteria, enhancing nutrient cycling and soil enzymatic functions.
10. Biochar serves as a long-term carbon sink, stabilizing carbon in soil for hundreds to thousands of years.
11. Woolf et al. (2010) estimated that biochar application to 10% of global croplands could sequester up to 1.8 gigatonnes of CO₂ annually.
12. Integrating biochar into agroforestry systems could potentially double carbon sequestration rates compared to monoculture systems.
13. It also contributes to greenhouse gas mitigation, with Major et al. (2010) reporting a 50% reduction in nitrous oxide emissions from tropical soils treated with biochar.
14. Recent studies demonstrated a 60% reduction in methane emissions from paddy fields using biochar-biofertilizer composites.

Representative Case Studies:

- Amazonian Terra Preta Soils (Brazil): Ancient dark earth soils created over 2,500 years ago with charcoal and organic waste maintain 3–7% SOC compared to 0.5% in adjacent soils (Glaser et al., 2001).
- ICAR-CAFRI, Jhansi: In Bundelkhand, biochar at 5–10 t/ha combined with organic manures increased pulses and oilseed yields by 10–20% and SOC by 0.3% over three years (Ramesh et al., 2022).
- IRRI, Philippines: Rice straw biochar reduced methane emissions by 40% and raised rice yield by 10–15%.
- IARI, New Delhi (2021): Biochar-nutrient composites enhanced maize yield by 18%, reduced synthetic fertilizer use by 25%, and increased soil microbial biomass by 30%.

Constraints in Biochar Adoption: Despite clear benefits, several limitations hinder adoption:

- High initial production and transportation costs.
- Absence of standardized quality benchmarks.
- Limited awareness and technical knowledge among farmers.
- Variation in biochar properties based on feedstock and production methods.
- Risk of nitrogen immobilization in low-fertility soils if not properly managed.

Policy Support and Future Prospects: The Indian government, through the National Mission on Sustainable Agriculture (NMSA), promotes biochar for soil health improvement. ICAR has

recommended incorporating biochar under the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) for moisture conservation in dry regions.

Advanced applications under investigation include biochar as a carrier for bio-inoculants, its role in constructed wetlands for wastewater treatment, and activated biochar filters for managing agricultural runoff.

Journey of Pyrolysis unit at UAS, Bangalore from the workshop to the fields

At the University of Agricultural Sciences, Bangalore, a significant initiative has been undertaken in the development and operationalization of a 500 kg/day capacity pyrolysis unit for biochar production. Fabricated in collaboration with an industry partner in Pune, the unit was installed at the GKVK campus in March 2024. It converts biomass waste into valuable by-products like biochar, bio-oil, and syngas, with the syngas being utilized for reheating the unit itself, minimizing external energy inputs. Initial operational trials have successfully demonstrated the production of biochar, and further activities are planned to assess its quality, optimize production cycles, and explore field applications for soil health improvement and crop productivity enhancement, alongside addressing environmental issues such as stubble burning.



Fig 1: Pyrolysis unit at UAS, Bangalore and production of biochar

Conclusion

Biochar is a multifunctional amendment capable of addressing soil degradation, boosting crop productivity, mitigating climate change, and sequestering carbon. With targeted policy initiatives, localized decentralized production, and farmer awareness programs, biochar could play a transformative role in Indian agriculture. Integrating functionalized and precision biochar applications in farming systems holds immense promise for building climate-resilient and productive agricultural landscapes.

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NANOTECHNOLOGY IN DIAGNOSIS AND CONTROL OF PLANT DISEASES

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Abstract

Nanotechnology has revolutionized various sectors of science and technology, and its application in agriculture, particularly in Plant Pathology, has gained considerable attention in recent years. Nanoparticles and nan sensors offer high precision in detecting plant pathogens and delivering agrochemicals in controlled manners. For example **“Gold nanoparticles enabled a 90% detection accuracy for Tomato Spotted Wilt Virus in field trials”** [Swales & Feak (2012)]. This article highlights the latest advances in the use of nanotechnology for the diagnosis and control of plant diseases, exploring mechanisms, materials used, examples, advantages, limitations, and future potential.

Keywords: Nanotechnology, Plant disease diagnosis, CRISPR, Biosensor, Nano formulation.

1.Introduction

The growing demand for increased agricultural productivity under climate change stress, coupled with the need for environmentally sustainable practices, has propelled the adoption of advanced technologies in crop protection. Plant diseases are one of the leading causes of reduced yield and poor quality, accounting for up to 30% of crop losses globally. Current diagnostic methods, such as PCR, ELISA, and culturing, though accurate, are often time-consuming and require laboratory infrastructure. Similarly, conventional pesticides suffer from issues like non-

specificity, resistance, and residual toxicity. Nanotechnology offers a paradigm shift through rapid, in-field diagnostics and precise, efficient control mechanisms.

2.Nanotechnology in Disease Diagnosis:

Nanotechnology enables the development of ultrasensitive biosensors and point-of-care diagnostic devices that can detect pathogens at their early stages, before symptoms become visible.

Nano-biosensors integrate biological recognition elements with nanomaterials to convert a biological interaction into a measurable signal. For instance, carbon nanotubes and graphene oxide have been utilized to detect nucleic acids of viral and bacterial pathogens with remarkable sensitivity.

Gold nanoparticles (AuNPs) are widely used due to their unique optical properties, especially in colorimetric detection. Lateral flow assays with AuNPs have been employed for detecting viruses such as Tomato Spotted Wilt Virus and Cucumber Mosaic Virus.

Quantum dots, due to their high photostability and tunable fluorescence, are employed in fluorescence based pathogen imaging.

Magnetic nanoparticles facilitate sample enrichment and separation, significantly improving the sensitivity of nucleic acid or protein-based assays.

3.Nanotechnology in Disease Control:

The management of plant diseases using nanotechnology revolves around the use of nanoparticles as carriers for active ingredients, antimicrobial agents, and elicitors of plant defense.

It includes:

Nano formulations -Agrochemicals are encapsulated or bound to nanocarriers like liposomes, micelles, and polymeric nanoparticles, ensuring controlled release, increased bioavailability, and reduced environmental runoff. For instance, nano-encapsulated azoxystrobin and mancozeb have shown enhanced efficacy against fungal pathogens.

Metallic nanoparticles - Silver (AgNPs), copper (CuNPs), and zinc oxide (ZnONPs) are prominent nanomaterials known for their antimicrobial activities. They generate reactive oxygen species (ROS) and disrupt pathogen cell membranes. AgNPs are especially effective against fungi like *Botrytis cinerea* and bacteria such as *Pseudomonas syringae*.

Chitosan nanoparticles - These biodegradable particles have dual functions: direct antimicrobial activity and stimulation of plant immunity. Foliar sprays of chitosan NPs reduce infections by Powdery mildew and Downy mildew.

Silica nanoparticles - Known for their adjuvant properties, they enhance the systemic movement of biopesticides within the plant.

Green synthesized nanoparticles -Synthesized using plant extracts, these NPs are eco-friendly and show comparable efficacy to chemically synthesized ones.

4.Field Applications and Case Studies:

Several studies and field trials have validated the effectiveness of nano-based plant protection solutions: - In tomato plants, foliar application of silver nanoparticles significantly reduced late blight severity caused by *Phytophthora infestans*.

- Copper nanoparticles in rice showed effective suppression of bacterial blight without phytotoxic effects.
- Nano chitosan applications in grapevines provided protection against *Plasmopara viticola*, the downy mildew pathogen.
- A diagnostic strip based on gold nanoparticles was successfully developed for early detection of Banana Bunchy Top Virus (BBTV) in field conditions.

5.Advantages of Nanotechnology in Plant Disease Management:

High precision - Target-specific detection and delivery minimize waste.

Early detection – Nano biosensors enable real-time monitoring of pathogens.

Reduced chemical use – Nano formulations require lower doses for effective control.

Environmental sustainability - Controlled release minimizes leaching and residues

Enhanced plant immunity - Certain nanoparticles induce systemic acquired resistance (SAR).

6.Challenges and Concerns:

Despite the benefits, widespread adoption of nanotechnology in plant disease management is limited due to several challenges:

Toxicity and environmental fate - Long-term effects of nanoparticle accumulation in soil and crops are not fully understood.

Regulatory issues - Clear policies for testing, approval, and labeling of nano-agrochemicals are lacking.

Cost of production - High manufacturing costs limit affordability for smallholder farmers.

Public perception - Lack of awareness and concerns over food safety hinder acceptance.

Future Perspectives:

The future of nanotechnology in plant pathology lies in the integration of nanosensors with wireless networks and AI-based decision-making tools for smart farming. Research is underway to develop:

- Multifunctional nanodevices for simultaneous detection and control (theranostics).
- Biodegradable and stimuli-responsive nano formulations.
- CRISPR-nano complexes for targeted genome editing in pathogen resistance breeding.
- Nanoscale delivery systems for plant vaccines and RNA interference (RNAi) molecules.
- Collaborations between plant pathologists, nanotechnologists, environmental scientists, and policymakers are essential to ensure safe and effective deployment.

Conclusion

Nanotechnology offers a powerful platform for addressing the limitations of conventional plant disease management. With advancements in materials science and increasing emphasis on sustainable agriculture, nanotech-enabled diagnostics and control methods are poised to transform plant health management. While challenges remain in terms of safety, regulation, and scalability, continuous research and responsible innovation will unlock the full potential of nanotechnology in safeguarding global food security.

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WATER CONSERVATION METHODS AND TECHNOLOGIES FOR GREEN ENVIRONMENT

Article ID: AG-VO5-I05-38**Santhosh, S¹, Krishnaveni, A² S. Manickam¹, M.S.Aneesa Rani²****P. Sumathi¹, M. Kavaskar¹, K. Sha¹, S. Sanjaygandhi¹ and S. Sathiyamurthi²****Agricultural College and Research Institute, Vazhavachanur, Tiruvannamalai****Horticultural College and Research Institute, Paiyur, Krishnagiri, Tamil Nadu, India*****Corresponding Author Email ID: krishnavenia@tnau.ac.in**

Introduction

Water is the source of life. All living beings on Earth – humans, animals, birds, marine life, and plants cannot survive without water. Our lives depend entirely on this natural resource, whether it's the water we drink every day, use for agriculture, or consume in industries. Despite its importance, water is becoming scarce today. The reasons include – increasing population, poor water management, deforestation, changes in rainfall patterns, and water pollution from industries. In this situation, "*water conservation*" becomes an essential task. Every step we take today to protect water will become a secure water source for us and future generations. In this essay, we will explain the traditional water conservation methods, modern technologies, and government contributions in simple Tamil. Water is a basic necessity for human life. However, one of the major problems we face today is water scarcity.

2. Importance of water conservation

2.1. Drinking Water Shortage

In our country, even in many villages and urban areas, accessing clean drinking water has become very difficult. Due to the drying up of water sources and reduced rainfall, people struggle to get water for their daily needs. This affects their health and overall quality of life.

2.2. Depletion of Groundwater Level

Groundwater is being over-extracted by farmers and for drinking water needs. However, due to insufficient rainfall to replenish these sources, groundwater levels are steadily decreasing.

This has turned into a major environmental issue

2.3. Declines in crop Yield

Agriculture is entirely dependent on water. However, due to the lack of water, many crops are unable to grow and wither away. This results in significant losses for farmers. It also poses a serious challenge to the country's food security. The study was undertaken to know the comparative effect of different water conservation technologies (Kondo et al., 1998)

2.4. Excess Water Wastage in Cities

In cities, wastewater and sewage often flow away without proper treatment. Due to the lack of rainwater harvesting systems, a large amount of water simply drains into the sea. There are many possibilities to conserve this water, but they are not being utilized.

2.5. The Role of Water in a Green Environment:

Trees, flowers, and green spaces all require water to grow. Without water, there is a risk that these natural resources will vanish. This can lead to climate changes and negatively impact the environment. Economic Analysis of Sprinkler irrigation in Southern Rajasthan (Acharyna *et al.*, 1993)

3. Water Conservation Methods

3. 1. Traditional Water Conservation Methods for Drinking and Irrigation

Our ancestors always respected water and followed various traditional methods to conserve and utilize it wisely. These methods were eco-friendly and met the needs of the people effectively. Even today, some of these methods are still in use in certain regions. Let us look at some important traditional water conservation techniques. Different water saving methods are available in irrigated farming (Dhawan, B.D.2002).

Village Ponds:

A *village pond* is a naturally formed pond found in villages. These ponds store rainwater and are used to supply drinking water and provide water for cattle. *village pond* also play a crucial role in groundwater recharge. Many of them are still functional today, though they require proper maintenance and restoration.

Lakes/Ponds

Lakes is a large water reservoir or tank, usually owned and used by the community. People drew drinking water from it, and it was also used to irrigate agricultural fields. Some Ponds were built near temples and served as a source of clean water for devotees, playing a vital

role in both daily life and spiritual practices.

Wells:

Wells are one of the oldest known water sources. They are dug to access groundwater. Found commonly behind homes and in agricultural fields, water is drawn from wells either manually or using electric motors. Even today, wells remain a primary source of water in many villages.

Rooftop Tanks:

Rooftop Tanks is a small tank or storage system installed on the rooftop of a house. It is an efficient method to directly collect rainwater. The rainwater stored through this method helps recharge the groundwater. It is highly beneficial for improving water levels.

Wetlands:

Wetlands are naturally occurring areas that retain water. They help in replenishing groundwater and play a vital role in maintaining a green environment. They also serve as habitats for various forms of wildlife. These areas are important ecological resources that must be protected.

Rainwater Harvesting:

Our country receives good rainfall every year. However, most of this rainwater goes to waste. The method of collecting and using this rainwater is known as *rainwater harvesting*. It is a simple, cost-effective, and environmentally friendly practice.

Roof top Rainwater Harvesting:

When rain falls on the rooftops of houses, it is collected through pipes. This water is then stored in a large tank or container. The collected water can be used for gardening, toilet needs, or, after purification, even for drinking purposes.

Percolation Pits for Groundwater Recharge:

A very effective method to prevent the depletion of groundwater levels. A pit of about 3 to 6 feet deep is dug near the house. This pit is filled with materials like stones and sand, allowing rainwater to seep through and recharge the groundwater table.

Rainwater Harvesting Systems in Schools, Offices, and Other Large Buildings:

The government and private institutions are required to include a rainwater harvesting

system while obtaining construction approval.

Rainwater collection systems are mandatory in places like schools, colleges, and hospitals.

This also helps raise awareness about water conservation among students and the general public.

Benefits of Rainwater Harvesting:

- Groundwater levels increase.
- There will be no disruption to the drinking water supply.
- It serves as a solution to water scarcity.
- It is an environmentally friendly practice that helps conserve nature.
- It increases the chances of water availability for agriculture.

Clay Canal Systems for Groundwater Management:

Groundwater refers to the water that seeps into the earth through rainfall. Today, the amount of groundwater is rapidly depleting. Proper management techniques are essential to rectify this issue. Below are some important methods. These canals, made from natural clay, have the ability to absorb both rainwater and irrigation water into the ground water. This method helps increase the groundwater level in the soil.

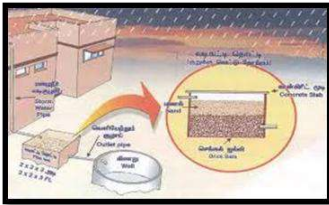
- Clay canals can be created at a low cost.
- Permeable Pathways for Water:
- Small channels or barriers are created to allow rainwater to seep into the soil.
- The water collects and gradually flows into the groundwater.
- This method is commonly practiced in rural areas.

Irrigation Planning:

With proper planning, irrigation can be done efficiently without wasting excess water. Modern techniques like drip irrigation and sprinkler systems allow for more efficient water use. This reduces the demand for groundwater.

Green Environment Development:

Activities like tree planting and establishing gardens help protect groundwater. The roots of trees allow rainwater to seep into the soil. A greener environment has a higher ability to attract rainfall.

		
Roof top Rainwater Harvesting	Percolation Pits	Rainwater Harvesting Systems in Schools
		
Clay Canal Systems	Irrigation Planning	

Conclusion

Water conservation is very important for the future human survival due to climatic variation and abrupt rainfall pattern. The cost effective and easy technologies are highly essential to adopt all types of famers like small, medium and women farmers.

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BIO-WEEDICIDES: A TOOL OF SUSTAINABILITY

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Introduction

Bio-weedicides, also known as bio-herbicides, are herbicides derived from natural sources like bacteria, fungi, or natural compounds, used to control weeds. Unlike synthetic herbicides, bioherbicides leverage biological agents to disrupt plant processes, aiming to selectively target weeds without harming crops. Bioherbicides are weed-control products derived from living organisms to suppress weed populations and comprise part of this reduced-risk strategy. Benefits of bioherbicides include short-lived environmental fate, multiple modes of action reducing the risk of herbicide resistance, and low toxicity. Bioherbicides offer an environmentally friendly approach to weed control in agriculture, using naturally derived agents like microbes, fungi, or plant extracts to suppress weeds. They can be applied as granules or sprays, similar to traditional pest control methods, and are effective in various settings, including naturally occurring areas and cultivated crops. Bioherbicides are particularly beneficial in managing weeds resistant to chemical herbicides.

Types of Bioherbicides:

- **Mycoherbicides:** Use fungi to target specific weeds, with examples like *Phytophthora palmivora* for milkweed control.
- **Seed-based bioherbicides:** Applied to seeds before planting to protect emerging crops from weed competition.
- **Allelochemical-based bioherbicides:** Utilize compounds released by plants that inhibit weed growth.

- **Plant extract bioherbicides:** Extracts from certain plants can suppress weed growth without harming desirable crops.
- **Fungal and bacterial pathogens:** Can be used to control weeds through diseases or toxins.
- **Essential oils:** Some essential oils exhibit herbicidal activity.
- Advantages of Bio-herbicides:
- **Environmentally friendly:** Bioherbicides minimize pollution and are less harmful than chemical herbicides.
- **Sustainable:** Bioherbicides can be part of integrated pest management strategies.
- **Effective against herbicide-resistant weeds:** Bioherbicides can help manage weeds that have developed resistance to chemical herbicides.
- Microbial bioherbicides may infect and damage weed plants, disrupt their growth, or produce compounds inhibiting weed development. Plant-derived bioherbicides often target specific biochemical processes crucial for weed survival.

Biological weed control is a mechanism to suppress the germination and growth of weed populations to an economic threshold level by utilizing natural enemies, natural substances, or biotic agents. Bioherbicide and conventional herbicide application methods are similar, although for mycoherbicides the pathogenic fungi are 'inoculated' by spraying the pathogens onto target weeds. Recently, bioherbicides have been regarded as a crucial weed control element [8], albeit not as a total replacement but rather as an alternative to chemical herbicides [9]. Sustainable weed management does not rely on any single weed management technique, unlike synthetic herbicides in conventional agriculture; therefore, bioherbicides should be used concurrently with other weed management techniques to control weeds.

Bioherbicides that are thought to be safer and 'greener' have drawn attention, as scientific reports provide increasing evidence of their efficacy. However, their commercial presence in comparison to conventional herbicides is relatively new. Therefore, rigorous testing and validation is necessary to evaluate their efficacy and reliability for weed control. This review explores the impact of bioherbicides, particularly plant-based, on weed physiology and the factors that influence their efficacy as well as the limitations of their use.

Biological control of weeds is the intentional use of living organisms (biotic agents) to reduce the vigor, reproductive capacity, density, or impact of weeds (Quimby and Birdsall, 1995). The



strategies of biological control can be classified in two broad categories: (i) classical or inoculative, and (ii) inundative or mass exposure. The classical strategy is based on introduction of host-specific organisms (insects, pathogens, nematodes) from the weed's native range into regions where the weed has established and become a widespread problem. The biotic agents, after quarantine to assure host specificity, are released into weed-infested sites and are allowed to adapt and flourish in their new habitat over time to eventually establish a self-perpetuating regulation of the weed infestation at acceptable levels. Thus, classical biological control requires a time period of one to several years to achieve adequate control while the agent population builds up to levels to impact the weed population.

It's important to note that bioherbicides are still being developed and studied, and their effectiveness and application can vary depending on the specific bioherbicide, target weed, and environmental conditions. Sustainability is ability to maintain or support a process over time. Sustainability is often broken into three core concepts: economic, environmental, and social. Many businesses and governments have committed to sustainable goals, such as reducing their environmental footprints and conserving resources. Sustainable agriculture is farming that meets the food and textile needs of the present without compromising the ability of future generations to meet their own needs. It focuses on long-term resource conservation, responsible resource use, and minimizing environmental impact.

Weedicides, while effective in controlling weeds, raise concerns about sustainability in agriculture due to potential environmental and health impacts. Sustainable weed management practices emphasize minimizing herbicide use and exploring alternative methods like biological control and integrated pest management. Biopesticides play a crucial role in sustainable agriculture by providing environmentally friendly alternatives to traditional chemical pesticides. They are derived from natural sources like plants, bacteria, fungi, or minerals and offer several benefits for the agricultural ecosystem. By reducing reliance on synthetic chemicals, biopesticides help preserve biodiversity, protect beneficial organisms, and contribute to overall soil and ecosystem health.

CRISPR-CAS9 GENOME-EDITING TECHNOLOGY IN RICE CROP

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Introduction

Agriculture is currently facing many obstacles such as global climate change, a rapidly growing population, pests and pathogens, and many environmental threats. The growing population makes food security an urgent, pressing issue all over the world, and there it is forecast that global food-supply demand will double from 2005 to 2050. Food security is being challenged by several factors including but not limited to climate change. It is one of the biggest challenges being faced by humanity not only in this era but can also probe the future generations, if not resolved. It is estimated that a huge chunk of worlds population does not have access to enough food for their survival for years, and about two million people are currently facing Production, nutrient deficiency, leading to their stunted growth as well. In such a critical situation rice (*Oryza sativa* L.) being one of the major food crops and a staple food worlds population, can play a pivotal role in global food security and can also be a key solution provider. Rice is highly sensitive to climate change as it requires optimum irrigation and a suitable temperature to grow normally. There fore swiftly changing climate scenario has become a central concern for the whole agricultural production system, especially rice, to ensure current and future global food security. Thus, being a major food crop, new climate smart rice cultivars should be developed that could withstand changing climatic conditions to feed the ever-growing human population and to end hunger, globality.

CRISPR-Cas9 genome-editing technology

In this regard GE system CRISPR-Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats) system provides a robust, efficient and economical mode of action that can alter the genetic makeup of crop plant without introducing foreign DNA, a major controversy in the acceptance through transgenic breeding method. This technology allows for precise genome-

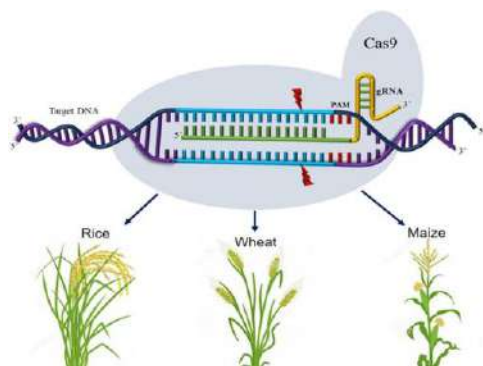


Fig No. 2:- Application of the CRISPR/Cas9 system for imparting agronomically important traits in rice, wheat, and maize

editing in crops, enabling improvement in traits like yield, quality, nutritional value, and stress resistance. It can be used to enhance pest and disease resistance, improve tolerance to abiotic stresses like drought and salinity, and even enhance shelf life and taste. The era of genome editing began with the introduction of zinc finger nucleases (ZFNs) and transcription activator-like effector nucleases (TALENs), though it reached new heights following the discovery of CRISPR/Cas technology.

The development of CRISPR/Cas9 (Clustered Regularly Interspaced Short Palindromic Repeats/CRISPR-associated nuclease 9) has revolutionized genome editing in plants, enabling significant advancements beyond the outcomes that conventional breeding techniques can achieve. The type II CRISPR/Cas9 system, which was initially found in *Streptococcus pyogenes*, has become the most widely adopted and extensively utilized system. The importance of genome-engineering technologies in modern plant development and improvement cannot be overstated. The field of genome engineering has undergone a transformative revolution, which was largely driven by the development and widespread acceptance of CRISPR, which is recognized as one of the most potent gene-editing techniques available. The CRISPR system functions by incorporating sequences from foreign elements into a small RNA-based memory,

which serves as an inherited resistance mechanism. These short RNAs recognize the foreign invader and employ Cas proteins, which act as enzymatic units, to cut and eliminate the invader's genetic material. In many aspects, the CRISPR system bears resemblance to the RNA-based defense mechanisms found in animal germ cells, which protect against mobile genetic material. The CRISPR-Cas9 system has been simplified into two key components: a single chimeric RNA known as guide RNA (gRNA) and the enzyme Cas9. Together, these elements enable the editing of specific genomes and facilitate desired modifications in genome engineering. The gRNA consists of CRISPR RNA (crRNA) and trans-activating CRISPR RNA (tracrRNA) sequences, which guide the sequence-specific cleavage of genomic DNA by Cas9 through a straightforward base-pairing process.

Notably, gRNAs can be easily designed to recognize a target sequence of 20 nucleotides in length and induce precise Cas9-dependent cleavage of both DNA strands at a pre-defined location within the target, underscoring the utility of this technology. The development of genome-edited plants using CRISPR/Cas9 technology consists of five steps: (i) selection of the target gene, (ii) designing a targeted gene-specific sgRNA, (iii) assembling Cas9 and sgRNA, (iv) transformation to the target plant, and (v) regeneration and screening of plant lines (see Figure 1). Here, we describe the usage and benefits of CRISPR genome-editing technology for developing plant lines that are resistant to disease and abiotic stress and provide examples of genes edited to enable crop improvement. (erdogan

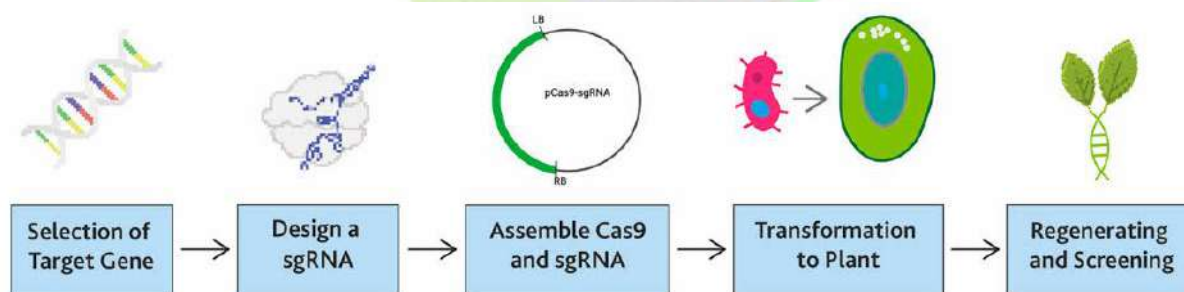


Fig. No. 2: - The basic flow of CRISPR/Cas9 technology used to edit target genes

Genome-edited Rice Varieties

Announcement of world's first ever two genome edited rice varieties development in India. DRR Dhan 100 (Kamala) and Pusa DST Rice 1 aimed at enhancing yield, climate resilience and resource efficiency without introducing foreign DNA. They have been developed by ICAR using advanced CRISPR-Cas9 genome-editing technology.

No foreign DNA is introduced, making them comparable to traditionally bred crops.

➤ **DRR Dhan 100 (Kamala):** It is based on the popular Samba Mahsuri variety. Edited using Site Directed Nuclease 1 (SDN1) technology targeting the cytokinin oxidase 2 (CKX2) gene (Gn1a) to improve grain number. Developed by: Dr. Satendra K. Mangrauthia, Dr. R.M. Sundaram & team ICAR- Indian Institute of Rice Research, Hyderabad.

Key Features: It results in 19% increase in grain yield, 15-20 days earlier maturity, Moderate drought tolerance, Retained grain quality

➤ **Pusa Rice DST1:** It is based on MTU1010 (Maruteru 1010) variety and enhances drought and salt tolerance. Developed through SDN1 genome-editing, it targets the drought and salt tolerance (DST) gene. Developed by ICAR- Indian Agricultural Research Institute, New Delhi (Dr. Viswanathan C. & Team)

Key Benefits: It results in needs less water-lower stomatal density, grows more-more tillers, bigger leaves, more grains, yield better-higher grain output even without stress, handles stress-performs well under drought & salt.

Conclusion

The emergence of CRISPR/Cas9 genome-editing technology has opened new possibilities and revitalized this field. With the integration of next-generation sequencing technologies, CRISPR/Cas9 has the potential to contribute to the development of future crops and mitigate the negative impacts of climate change on global food production. CRISPR-Cas9 technology has transformed genetic research by enabling precise and efficient gene editing, extending its applications beyond crop improvement in agriculture. Recent research explores CRISPR-Cas9's potential in soil microbiome engineering, pest control, disease resistance, and livestock feed improvement, each offering unique contributions to agricultural sustainability and productivity.

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BEYOND THE USUAL: EXPLORING THE RICH DIVERSITY OF COUNTRY FRUITS LEFT UNTAPPED

Article ID: AG-VO5-I05-41**Monisha V¹ and Senthamarai selvi L^{1*}**

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Introduction

Indian date palm/Wild date palm: *Phoenix sylvestris*

Vernacular names: Kajur (Hindi), Kaattiintha (Malayalam), Eecham pazham (Tamil), eetha pallu (Telugu), ichalu (Kannada).

Native to Indian sub continent. Trunk marked by a unique “wicker” pattern from old leaf scars makes it easily recognizable. Drought tolerant and hardy, this palm plays a key role in traditional medicine. Fruit is sweet and sour, used to treat fever, diabetes, coughs and urinary issues. The roots, known for antimicrobial properties used as natural toothbrushes. In rural India, flowers are tapped to make sugar and alcohol.



Wild melon: *Cucumis callosus*

Vernacular names: Kachri (Hindi), Budamkaya (Telugu), Chibbadin (Punjabi), sukkankai/ mithukankai (Tamil)



A small, oval fruit native to Rajasthan's Thar desert. Resembling a tiny watermelon, it has a bitter-sour taste that mellows as it ripens. It can be eaten fresh, cooked pickled and also used in chutneys or as meat tenderizer. Medicinally, it is known for stimulating appetite, supporting kidney health and helps in detoxification. Rich in magnesium and vitamin C. It can be used for blood sugar regulation, brain function, skin health promoting

collagen production and wound healing.

Prickly pear: *Opuntia ficus-indica*

Vernacular names: Nagphani (Hindi), Papasu kalli (Kannada), Sappathikalli (Tamil), Brahma Jamudu (Telugu), Palakakkalli/Rakthakally (Malayalam)



Prickly pear, the fruit of cactus plant, offers more than just vibrant colour and sweet taste it also rich in nutrients. Rich in antioxidants and flavanoids, it may help reduce inflammation and protect against oxidative stress which are linked to cholesterol and diabetes. It has high fiber content also supports digestion and blood sugar balance. Prickly pears provides vitamin C, magnesium, potassium and smaller amounts of calcium and B vitamins which play key roles in energy, immunity and heart health.

Indian blackberry: *Syzygium cumini*

Vernacular names: Jamun (Hindi), Neredu (Telugu), Kattuchampa/Naval (Malayalam), Naval (Tamil), Nerale (Kannada).



Jamun, also known as Indian blackberry, is a nutrient-rich fruit renowned for its medicinal properties. It contains vitamins, minerals, and powerful antioxidants. Traditionally used in ayurveda, jamun helps manage diabetes, boosts digestion, and strengthens immunity. Its seeds, pulp, and bark have been found effective against ulcers, high cholesterol, liver damage, infections, and inflammation. Scientific studies, mostly on animals, show promising results in reducing blood sugar, improving kidney and brain health, and offering anti-arthritis and anti-allergic benefits. With its antimicrobial, antioxidant, and anti-inflammatory effects, jamun holds potential as a natural remedy for numerous chronic health conditions.

Wood apple: *Limonia acidissima*

Vernacular names: Bael (Hindi), Vilam Palam (Tamil), Koovalam pazham (Malayalam), Vellaga Pandu (Telugu), Belada Hannu (Kannada)

Wood apple native to south India and Sri Lanka, is known for its distinctive taste and numerous health benefits. While the unripe fruit is quite acidic, the ripe fruit develop a pleasant, aromatic flavor. Traditionally, various parts of the plant including the leaves, barks, roots, fruits and seeds have been widely used in ayurvedic medicine.



They are especially valued for treating diarrhea, dysentery, peptic ulcers and natural laxative. Modern research supports the therapeutic potential of wood apple, include antitumor, antimicrobial, antidiabetic, anti-inflammatory, analgesic, antioxidant, antimutagenic and antimalarial effects.

Jackal Jujube: *Ziziphus oenopolia*

Vernacular names: Makkay (Hindi), Cheriyalantha (Malayalam), Surai ilantai (Tamil), Pariki (Telugu), Chee mullu (Kannada)

Fruits are rich in antioxidants, vitamin C, B vitamins, calcium, potassium, phosphorus, iron and dietary fiber which supports digestion, cardiovascular health, bone strength and weight management. The stem and roots are traditionally used to treat ulcers, stomach issues, asthma due to their anti-inflammatory and anti-bacterial effects. Studies suggest that potential for anti-diabetic and liver protective benefits.



Ground cherry/Sun berry – *Physalis minima*

Vernacular names: Tulati pati (Hindi), Sanna budda gida (Kannada), Sodakku thakkali (Tamil), Budama (Telugu), Njottanjodiyan (Malayalam)



Physalis minima is also known as golden berries are rich in nutrients offering various health benefits. They are high in Vitamin A, C, K and B-complex along with minerals like iron, calcium and phosphorus. Low in calories and fat, high in fiber supports weight management and digestion. Traditionally used in ailments like fever and spleen disorders, diuretic, analgesic and vermifuge. The skin of golden berries contains nearly three times more antioxidants than the pulp. Eating whole fruit maximizes their health benefits.

Ivy gourd: *Coccinia grandis*

Vernacular names: Kundru (Hindi), Tondekayi (Kannada), Dondakaya (Telugu), kovai (Tamil).

Ivy gourd is nutrient rich vegetable rich in vitamin A, C, B1 and B2 along with iron, calcium and fiber. High fiber and low calorie supports digestion, weight management and overall health. It also offers immune-



boosting vitamin C and antioxidant compounds like beta-carotene. It also offers immune-boosting vitamin C and anti-oxidant compounds like beta-carotene. It also promotes healthy skin and hair; helps prevent constipation and kidney stones.

Bengal currant: *Carissa carandas*

Vernacular names: Karonda (Hindi), Kalakkai (Tamil), Karikayi (Kannada), Pedda kalivi (Telugu), Karakka (Malayalam)



Karonda is a nutrient rich fruit with Vitamin C, A, iron, calcium, phosphorus and dietary fiber. It supports digestion, boosts immunity and promotes skin health due to its antioxidant and anti-inflammatory properties. Medicinally, aids in relieving indigestion, bloating and skin infections. Vitamin and mineral content of fruit helps to reduce fever, support mental well-being and regulate blood sugar levels.

Proanthocyanidins present in the fruit promote urinary tract health. Traditionally, it's used for treating ear aches, diarrhoea and itches.

Manila tamarind/Jungle jalebi: *Pithecellobium dulce*

Vernacular names: Kodukkaapuli (Tamil), Seema Hunase (Kannada), Seema Chintakaya (Telugu), Manilapuli (Malayalam).

Originating from Mexico, karonda spread to America, central Asia and India. Fruit is valued for its sweet tart pulp and medicinal properties. Nutritionally, it is rich in vitamin A, B (thiamine, riboflavin), C, fiber, protein, calcium, phosphorus and iron. Traditionally the bark, leaves and pulp are used to treat gum ailments, tooth ache, bleeding, chronic diarrhoea and inflammation. The astringent and haemostatic properties of the bark and pulp help manage oral issues and bleeding. Bark extracts are also used for constipation and tuberculosis.



Indian jujube- *Ziziphus mauritiana*

Vernacular names: Bugari mara (Kannada), Ber (Hindi), Gongarenu (Telugu), Elanthai pazham (Tamil, Malayalam),

Indian jujube is native to India and Southeast Asia. Rich in Vitamin C, A and B-complex vitamins supports immunity, vision and energy metabolism. It also provides essential minerals like calcium, iron and potassium and is high in dietary fiber, aiding digestion and preventing constipation. Low in



calories and packed with antioxidants, it promotes skin health and fights inflammation. Traditionally, it is used to treat insomnia, stress, respiratory issue and infections.

Ice apple: *Borassus flabellifer*

Vernacular names: Thati Munjaalu (Telugu), Panangnanguin (Malayalam), Panai/Nungu (Tamil), Tariya (Hindi), Tateningu (Kannada)



Ice apple (Palmyrah) is a hydrating, nutrient-rich fruit known for its cooling properties and multiple health benefits, especially in summer. It contains water, electrolytes and natural sugars that help prevent dehydration and boost energy. Rich in vitamins A, B, C and minerals like potassium, calcium, iron and zinc. It supports immunity, digestion and heart health. High fiber content aids bowel movements

and relieves constipation. With soothing and inflammatory effects, it soothes skin irritations and promotes healthy complexion. The fruit seeds are also edible. They are a good source of carbohydrates, proteins, and minerals like potassium and phosphorus.

Banyan Fig: *Ficus benghalensis*

Vernacular names: Bargad (Hindi), Marri (Telugu), Aalada (Kannada), Aalam Pazham (Tamil, Malayalam)

Native to Indian sub-continent, the banyan tree has long been valued in traditional medicine. Various parts of tree such as bark, leaves, fruits and latex are used to treat ailments such as dysentery, diarrhea, diabetes, leucorrhoea and wounds. Fruit is nutri-dense superfood rich in vitamins A,



C and K as well as minerals like calcium, iron and potassium. It also contains high levels of antioxidants and dietary fiber, supporting digestive health, aiding in weight management.

Noni Tree: *Morinda citrifolia*

Vernacular names: Nuna (Tamil), Sapanga (Kannada), Togaru (Telugu), Cherumanjanathi (Malayalam), Surangi (Hindi)

Noni is nutrient rich fruit native to Southeast Asia. It contains essential vitamins like C and A, minerals such as potassium and iron. Juice is high in antioxidants, including beta carotene, iridoids and vitamin E which combat oxidative stress. With low glycemic index, it



Noni

supports blood sugar control. Medicinally noni is known to boost immunity, reduce

inflammation and supports digestion. It may also aid in weight management, relieve management, relieve arthritis pain and lower uric acid levels, potentially reducing gout risk.

Wild Sage: *Lantana camera*

Vernacular names: Raimuniya (Hindi), Pulikampa (Telugu), Unnichedi (Tamil), Kakke Natahu (Kannada).



Lantana is native to Central and South America, introduced to India. It has anti-inflammatory, anti-bacterial and anti-fungal properties, effective in managing conditions such as fever, cold, coughs, headaches, skin infections and digestive disorders. Lantana fruits are commonly prepared in form of decoctions or infusions and used to alleviate gastrointestinal complaints including stomach aches, diarrhea and dysentery.



BIO FERTILIZERS FORMULATIONS & EM SOLUTION IN ORGANIC AGRICULTURE

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Introduction

Biofertilizers are emerging as a panacea for organic and sustainable agriculture. Scientifically, it is augmenting the soil with agriculturally beneficial microorganisms for attaining sustainability in agriculture. Establishing an environmental friendly co-existing mechanism on earth is of vital importance. In recent years, agrochemicals are extensively applied to obtain higher yield. Intensive application of agrochemicals leads to several agricultural problems and poor cropping systems. In modern agriculture, due to heavy usage of chemical fertilizers and harmful pesticides on the crops, sustainability of the agriculture systems collapsed, cost of cultivation soared at a high rate, income of farmers stagnated and food security and safety became a daunting challenge. Therefore, Bio-fertilizers offer a safe option to utilize renewable inputs to improve the fertility of land using biological wastes with those beneficial microorganisms which impart organic nutrients to the farm produces.

Biofertilizers are the preparations containing live or latent microorganisms, and a formulation enables easy handling, long-term storage, and effectiveness of biofertilizers. It is a delivery vehicle of live microorganisms from the factory to the field. A bioformulation is a state of carrier in which live or latent microorganisms (bioinoculants) are being supplied to the target, either plant or soil. The success of bioinoculant technology depends on two factors, microbial strain and inoculant formulation. Practically, formulation determines potential success of inoculants). Technological advancement in formulation is independent of strain of microbes used, as they share many physiological properties. In such a situation, the technology for one

strain can be used for other related strains with minor modifications. The success of bioinoculant technology depends on two factors, microbial strain and inoculant formulation. Practically, formulation determines potential success of inoculants. Technological advancement in formulation is independent of strain of microbes used, as they share many physiological properties. In such a situation, the technology for one strain can be used for other related strains with minor).

Effective Microorganisms EM Solution is a compound microbial preparation, including more than 80 microorganisms in 10 genera, including lactic acid bacteria, photosynthetic bacteria, actinomycetes, and yeast. It has a positive effect on soil deterioration, continuous cropping obstacles, crop disease resistance, yields and quality. Many kinds of bioinoculants are being used in agriculture like N fixers, P solubilizers, P mobilizers, biocontrol agents, PGPR, etc. For application, these bioinoculants have to be put in carrier, either liquid or solid based, along with osmoprotectant, sticking agents, nutrients, etc.; the complete assembly thus prepared is called a bioformulation. A formulation may differ according to the bioinoculant's use, type of soil, type of plant, nature of application, availability of resources, etc. Thus, the understanding of bioformulation is very much necessary as it affects the abundance and performance of bioinoculants. Thus, the formulation step is very crucial to developing a successful biofertilizer.

It is the industrial "art" of converting a promising laboratory-proven bacterium into a commercial field product. PGPM inoculants can be defined as formulations containing one or more beneficial microorganism strains (or species) prepared with an easy-to-use and economical carrier material. The development of techniques for the production of large quantities of pure inocula with high infectivity potential is the main issue to be tackled in order to allow a wide use of biofertilizers. The key aspects in PGPM inoculation technology are the use of a proper formulation of inocula preparations, the selection of an adequate carrier, and the design of correct delivery methods.

Basic characteristics of formulation:

- a. To stabilize the organism during production, distribution and storage.
- b. To deliver easily to the field in the most appropriate time.
- c. To protect the microorganism from adverse environmental factors at the target site (field), thereby increasing persistence.

- d. To enhance activity of the organism at the target site by increasing its viability, reproduction, contact and interaction with the target crops.

EM bacteria can form a favorable environment for crop growth and development. Improve soil physical and chemical properties and structure, promote the formation of soil aggregates, and improve soil fertility. EM bacteria can accelerate the decomposition of soil organic matter, significantly increase the effective content of soil nutrients, greatly enhance the rapid breeding of soil microorganisms, inhibit the invasion and development of soil pathogenic microorganisms, and form a favorable soil suitable for crop growth. EM bacteria can inhibit the reproduction of pests, promote the production of beneficial microorganisms, and fundamentally change the entire plough layer of the soil, which not only improves the biological activity of the soil, but also significantly enhances the buffer capacity of the soil.

Effective Microorganisms (EM) technology enhances organic farming by improving soil health, promoting plant growth, and reducing the need for chemical inputs. EM is a consortium of beneficial microbes that naturally occur in soil and can be applied to enhance microbial diversity and improve soil quality. Microorganisms are tiny units of life that are too small to be seen with the naked eye and they exist everywhere in nature. Microorganisms are crucial for maintaining the ecological balance. They carry out chemical processes that make it possible for all other organisms including humans to live. There are friendly guys of the microbial worlds known as beneficial microorganisms and a not so friendly group called pathogens that are harmful and capable of producing disease, decay and pollution..

EM inoculation to the soil can improve the quality of soil, plant growth and yield (Han et al., 2006). Healthy soil ecology has the capability of protecting plants against soil born diseases caused by pathogenic microorganisms and parasites. The soil system offers this protection through a balanced relationship between pathogenic and billions of beneficial microorganisms working together in synergy. Chan et al., (2003) observed that presence or absence of these beneficial microorganisms in any soil system precisely distinguishes “living soil” from a “dead soil”. They decompose and ferment organic fraction of the soil system converting it into humus containing nutrients while releasing hormones that facilitate plant growth. They are responsible for providing hormones, nutrients and minerals to the plants through the root system. In addition, they bring together soil particles in the soil structure enabling it to retain nutrients and moisture (Kengo and Hui-lian, 2000).



Effective microorganism enhances the activities of beneficial indigenous microorganisms, for example, mycorrhizae (ecto as well as endomycorrhizae) which fix atmospheric nitrogen and accelerate phosphorus and zinc uptake from soil thereby supplementing the use of chemical fertiliser and pesticides. Improvement in soil fertility has a significant positive effect on plant growth, flowering, fruit development and ripening in crops .





BOTANICA OF GROUNDNUT

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Introduction

Groundnut (*Arachis hypogaea* L.), commonly known as peanut, holds considerable importance as a food legume, particularly in tropical and subtropical regions. Globally, it is ranked 13th among the principal economic crops due to its multifaceted role in food, feed, and oil production (FAO, 2021). Groundnut cultivation spans nearly 90 countries across various agro-climatic zones, illustrating its adaptability and economic value. The crop is particularly valued for its high oil content, protein richness, and role in improving soil fertility through nitrogen fixation (Patel et al., 2020).

The crop's origin has long been a subject of scholarly debate. While some historical and botanical evidence suggests that groundnut originated in South America, particularly in the region of present-day Brazil, other theories propose that it may have been domesticated in parts of Africa due to its early presence in African agricultural systems and its integration into local diets and trade networks (Nigam, 2014; Hakeem et al., 2020). Despite the uncertainty surrounding its origin, groundnut cultivation has expanded significantly in several regions of the world. At present, the major producers of groundnut include India, China, the United States, Senegal, Indonesia, Nigeria, Brazil, and Argentina (FAOSTAT, 2023). These countries have established extensive farming systems and research programs dedicated to maximizing yields and improving varieties.

In India, which is among the top groundnut-producing countries, the crop is mainly grown in six states: Gujarat, Andhra Pradesh, Tamil Nadu, Karnataka, Maharashtra, and Rajasthan. These states contribute the majority of the national production due to favorable climatic conditions and established agricultural infrastructure. Other states like Madhya Pradesh, Uttar Pradesh, Punjab, Odisha, and West Bengal also engage in groundnut farming, though on a smaller scale (Government of India, 2024).

According to the Second Advance Estimates released by the Government of India for the agricultural year 2023–24, groundnut production is expected to reach approximately 86.54 lakh tonnes. However, this represents a decline from the 2022–23 season, where production was recorded at 102.97 lakh tonnes. The productivity too has decreased, from 2075 kg/ha in the previous year to 1953 kg/ha in 2023–24 (Ministry of Agriculture & Farmers Welfare, 2024). This decline could be attributed to erratic weather patterns, changes in input use, or pest and disease pressures.

In Tamil Nadu, one of the key groundnut-growing states, around 2.77 lakh hectares were brought under groundnut cultivation during the 2023–24 season. The state achieved a production level of approximately 7.00 lakh tonnes, with an impressive productivity rate of 2529 kg/ha, which is significantly higher than the national average (Department of Agriculture and Farmer's Welfare, Tamil Nadu, 2024). This high yield reflects the state's adoption of improved agronomic practices, quality seed use, and efficient water management systems. (INDIASTAT, Groundnut: second advance estimates 2023-24.)

GROUNDNUT

Groundnut (*Arachis hypogaea* L.), commonly referred to as peanut, ranks as the third most significant oilseed crop globally, following soybean and rapeseed. Its importance stems not only from its contribution to edible oil production but also from its multifaceted uses in food, feed, and industry. The term "groundnut" originates from the Greek words *Arachos*, meaning "a weed," and *hypogaea*, meaning "beneath the earth," thus describing a plant whose fruits develop underground. This subterranean fruiting behavior, technically referred to as *geocarpy*, has earned groundnut the nickname "the unpredictable legume," as the productivity of its hidden pods is not always visible from the above-ground plant morphology (Pattee and Stalker, 1995).

Botanically, groundnut is classified as a self-pollinated, annual, herbaceous legume. It completes its life cycle within a single growing season and exhibits an erect or prostrate growth

habit with thin, branched stems and pinnate, feather-like leaves. One of the most defining features of the groundnut plant is its reproductive process: after pollination, a unique structure known as the "peg" (or gynophore) elongates from the fertilized flower and penetrates the soil, where it matures into the pod. This geocarpic adaptation—where flowers pollinate above ground and pods develop underground—is rare among crops and plays a crucial role in groundnut's physiology and agronomy (Smith, 2002). The plant typically bears yellow, orange, cream, or white flowers, which are capable of self-pollination. After fertilization, the downward-growing peg pushes the ovary into the soil, initiating pod development. Groundnut seeds, commonly called kernels, are highly nutritious and form an essential component of both human and animal diets. The seeds comprise approximately 40–50% oil, 20–30% protein, and 10–20% carbohydrates, making groundnut an energy-dense food source (Savage and Keenan, 1994). Additionally, groundnuts are rich in essential micronutrients, including vitamin E, niacin, folic acid, calcium, phosphorus, magnesium, potassium, zinc, iron, riboflavin, and thiamine. Owing to their high nutritional value, groundnut kernels are widely consumed in various forms such as raw, roasted, boiled, or processed into peanut butter and confectionery items. Furthermore, groundnut oil, extracted from the seeds, is extensively used in cooking across many parts of the world due to its pleasant flavor and high smoke point.

In addition to human consumption, groundnut and its by-products serve several agricultural and industrial functions. The residual cake obtained after oil extraction is a rich source of protein and is commonly used as livestock feed or organic fertilizer. The green parts of the plant and straw are also fed to animals, while the shells and oil pressings are utilized in the manufacture of compost and other industrial products. These diverse applications make groundnut an economically viable cash crop, particularly in developing countries where it plays a pivotal role in improving farmers' livelihoods and supporting agro-industrial development (Nwokolo and Smartt, 1996).

Globally, the utilization of groundnut is divided into three major sectors. Approximately 53% of the total production is crushed to produce edible oil, 32% is processed for direct human consumption as snacks or in confectionery, and the remaining 15% is allocated for livestock feed and seed production (FAOSTAT, 2023). This broad range of uses underscores the versatility of the crop and its significant role in both domestic and international trade.

BOTANICAL CLASSIFICATION OF CULTIVATED VARIETIES

Taxonomically, cultivated groundnut (*Arachis hypogaea* L.) has been categorized into several botanical varieties based on morphological and agronomic traits such as growth habit, pod and seed characteristics, and flowering patterns. These classifications are important for breeding and crop improvement programs, as they influence yield potential, adaptability, and resistance to pests and diseases.

The cultivated groundnut (*Arachis hypogaea* L.) is classified into four major botanical varieties—Virginia, Peruviana, Spanish, and Valencia—each believed to have evolved in different regions of South America. Each of these types exhibits distinct characteristics and is believed to have evolved in different geographical regions (Stalker & Moss, 1987). These varieties exhibit distinct morphological traits and ecological adaptations, and their evolutionary history reflects both natural selection and indigenous cultivation practices over centuries.

The **Virginia** variety is thought to have originated in the Amazon Basin, where favorable climatic conditions may have contributed to its development. In contrast, the **Peruviana** variety is the most commonly identified type in ancient archaeological sites located in the arid coastal oases of Peru. It is believed to have been domesticated in that region, highlighting its historical significance in early South American agriculture (Simpson et al., 2001). The **Spanish** variety has its roots in northeastern Brazil, where it was widely cultivated by indigenous populations. The **Valencia** variety is believed to have been selected and developed by the Guarani communities inhabiting the Paraguay–Paraná river basin, a region known for its rich biodiversity and ancient agricultural practices (Stalker & Simpson, 1995).

The *Virginia* variety is characterized by large pods, a spreading growth habit, and late maturity. It is commonly grown in the United States and parts of India. The *Valencia* type is notable for its multiple-seeded pods and upright growth, making it suitable for shorter growing seasons. *Spanish* groundnuts are generally smaller in size, with compact plants and early maturity, making them ideal for semi-arid regions. The *Peruviana* type, though less commonly cultivated, represents a unique gene pool that contributes to genetic diversity within the species. Ongoing investigations into the statistical significance and genetic basis of these taxonomic classifications have provided valuable insights into the evolution, adaptability, and genetic improvement of peanut cultivars. Understanding the classification system helps researchers and

breeders select appropriate varieties for different agro-ecological zones and optimize yield through targeted breeding strategies

referred to as "runners" or "spreading types." This habit is due to the lateral branches growing horizontally and remaining close to the soil surface, creating a spreading canopy. The Peruviana type, in particular, exhibits more dense trichomes (hairiness) and longer branches compared to the Virginia type, which is comparatively less hairy and has shorter lateral stems (Krapovickas & Gregory, 1994). Both Virginia and Peruviana varieties typically have *seed dormancy*—a trait beneficial in wild or semi-domesticated species for survival—and require a relatively long growing season of four to six months for full maturity.

In contrast, the Valencia and Spanish types exhibit an *erect* growth habit, hence are referred to as "bunch types" due to the upright orientation of their branches that give the mature plant a compact, bushy appearance. These types are more suited to shorter growing seasons, requiring only three to five months to mature. Unlike their prostrate counterparts, Valencia and Spanish groundnuts do not exhibit seed dormancy, allowing for quicker germination and crop turnover (Nigam et al., 1990).

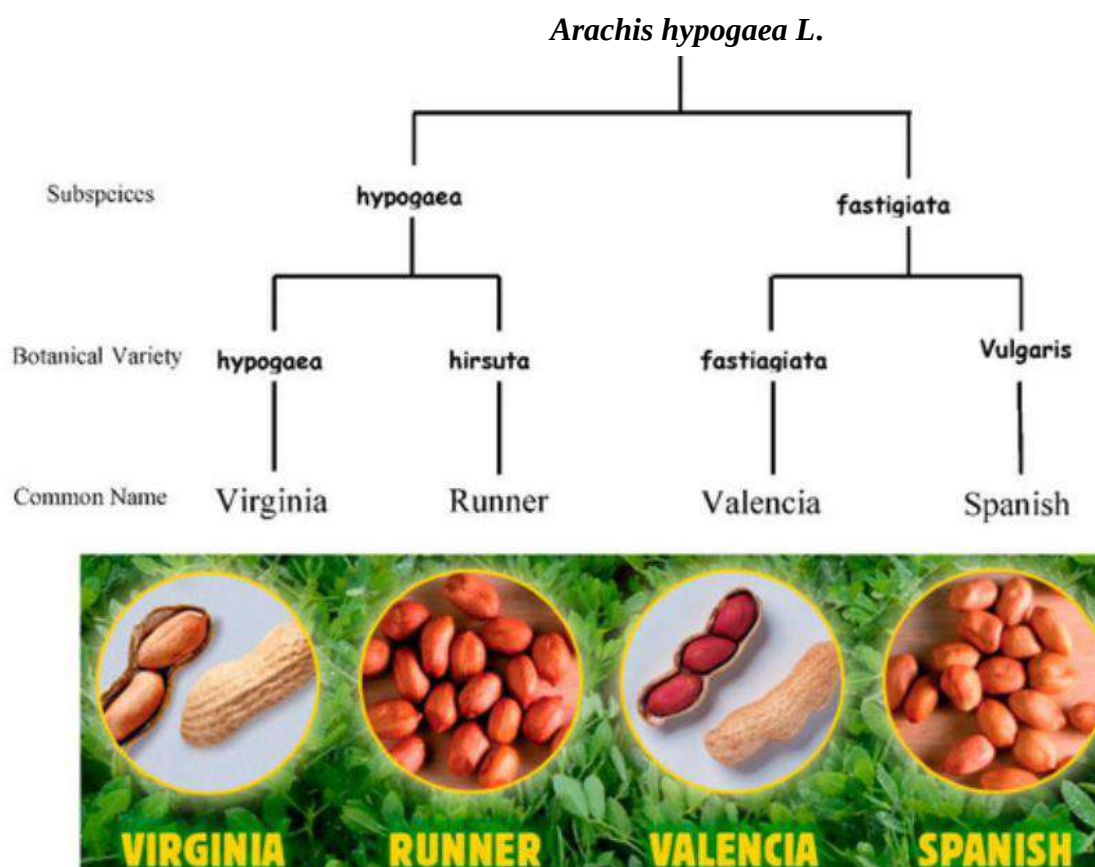
Subspecies	Varieties	Botanical type	Branching pattern	Growth habit	Seed/pod
<i>hypogaea</i>	<i>hypogaea</i>	Virginia	alternate	Prostrate to semi-erect	2-3
	<i>hirsuta</i>	Peruvian runner	alternate	Prostrate	2-4
<i>fastigiata</i>	<i>fastigiata</i>	Valencia	sequential	Erect	3-5
	<i>vulgaris</i>	Spanish	sequential	Erect	2

Morphologically, these varieties differ not only in appearance but also in growth habit and agronomic traits. The Virginia and Peruviana types are characterized by a *prostrate* growth form, often In terms of branching, the Spanish variety is typically more branched than the Valencia type, which is only modestly branched. This structural difference influences pod production and plant density in field conditions. Although erect types such as Spanish and Valencia tend to have lower individual pod yields per plant when compared to spreading types,

they are often favored for their higher seed oil and protein content. Notably, the Spanish variety is particularly rich in oil, making it an economically valuable type for oil extraction industries (FAO, 2021). The compact nature of the erect types also allows for higher planting density, which can partially offset their lower per-plant yield in terms of overall land productivity.

Most widely adopted classification of groundnut (*Arachis hypogaea* L.)

Interestingly, accessions of the Peruviana runner (also known as *var. hirsuta*) are rare in global germplasm repositories, highlighting the need for conservation and inclusion of these



underrepresented genetic resources in breeding programs to preserve biodiversity and enhance resilience in groundnut cultivation (Holbrook et al., 2008). However, Gibbon et. al. (1972) described the subspecies and botanical varieties in details as follows:

Arachis hypogaea L. (Linnaeus, 1753)

Subsp. *hypogaea* (Krapovickas and Rigoni, 1960)

Habit prostrate or erect, branching alternate; inflorescences simple and never borne directly on main axis; first branch on cotyledonary axis always vegetative; 2 or 2-3-4 seeds per pod; pod beak pronounced, small or absent; pod constrictions pronounced, moderate or absent;

pod diameter very large 20 mm + to small 10 mm or less; testa colour commonly brown but red, white and purple forms are recorded; seed dormancy usually present; foliage dark green in colour. (Gibbons et al., 1972)

Var. *hypogaea* (type 'Virginia' (Gregory et al., 1951)

Habit procumbent, decumbent or erect; main axis in procumbent forms short (not exceeding 40-50 cm); stem usually not very hairy; usually two-seeded; pod beak generally not very prominent, medium-late maturing.

Var. *hirsuta* Kohler (type 'peruano', Dubard, 1906)

Habit procumbent; main axis may exceed 1 m; stem fairly hairy; pods strongly beaked and ridged, with two to four seeds; very late maturing.

Subsp. *fastigiata* Waldron (Waldron, 1919)

Habit erect or decumbent; branching sequential; inflorescence simple or compound, always present on main axis; first branches on cotyledonary laterals reproductive; seed dormancy usually absent; foliage usually lighter in colour than in subsp. *hypogaea*.

Var. *fastigiata* (type 'valencia', Gregory et al., 1951)

Vegetative branches on primaries absent or regularly placed at the distal nodes; inflorescence usually simple; pods with two or two to four (rarely five) seeds; beak absent, slight or prominent; size medium to small; testa colour tan, red, white, yellow, purple or variegated.

Var. *vulgaris* Harz (=type 'spanish', Gregory et al., 1951)

Vegetative branches occasional and irregularly placed; inflorescence compound; pods usually with 2 seeds; beak present or absent; size medium to small; testa colour tan, red, white, or purple

BOTANICAL CHARACTERISATION OF GROUNDNUT:

Habitat: A warm season crop; requires dry weather for ripening and harvesting; suitable to soils of well drained, loose, friable, sandy loams.

Habit: Erect or trailing, sparsely hairy, annual herb.

Roots: Taproot with many lateral roots; nodules usually present.

Stem: Dimorphic branching; monopodial vegetative branches produced from each node above the main axis. Reproductive branches develop singly at nodes on monopodial branches. A single flower, subtended from leaf axil with reduced leaf in the axils, represents the reduced

reproductive branch. The arrangement of monopodial and reproductive branches results in alternate and sequential branching pattern. Sequential branching results when the central axis produces a few erect monopodial branches from the lower nodes followed by reproductive branches from the next nodes before ending in a series of sterile axils.

Leaves: Phyllotaxy spiral; two to five pinnately compound with two opposite pairs of obovate leaflets; leaflet entire; stipules prominent, adenate to petiole for less than half their length; petiole long, pulvini at point where stipules become free and at base of each leaflet, cause characteristic sleep movements in which the petiole folds downwards and the leaflets folds upwards until they touch.

Inflorescence: Flowers borne on compressed spikes in the axils of foliage leaves; one to several flowers present most abundantly at lower nodes.

Flowers: Sessile, yellow in colour, bisexual, zygomorphic and complete.

Calyx: Calyx tube elongates as bud develops; long, very slender and often mistaken for pedicel; five lobed with four fused into a superior lip, above standard petal and fifth linear tooth below keel petal.

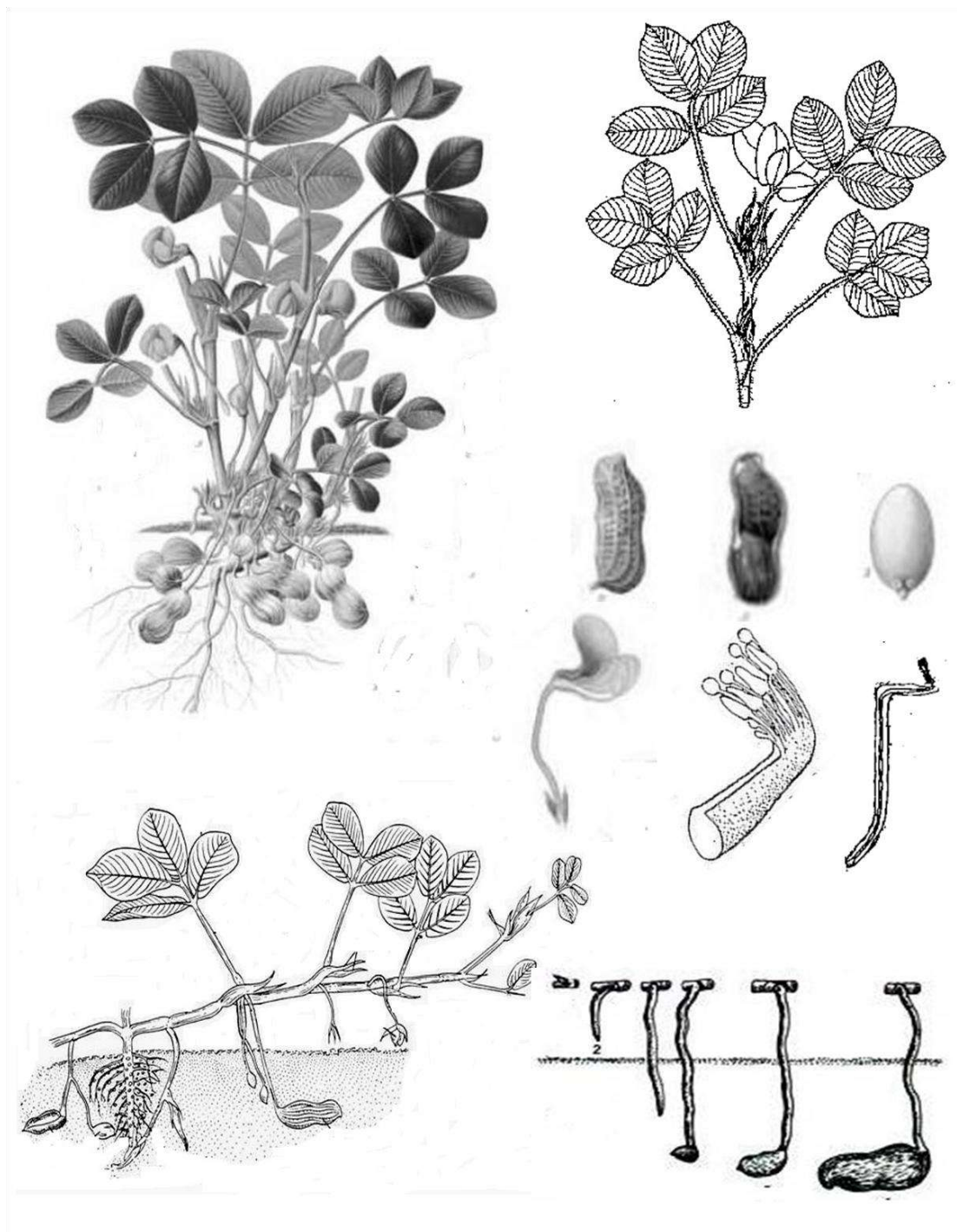
Habitat: A warm season crop; requires dry weather for ripening and harvesting; suitable to soils of well drained, loose, friable, sandy loams.

Corolla: Papilionaceous; petals and staminal column adenate at base and inserted on top of calyx tube; petals five; standard yellow.

Androecium: Stamen ten, monadelphous, filaments fused for more than half their length; two stamen (opposite standard) sterile, four stamens with oblong, bilocular, introrse anther alternating with four stamens with smaller, globose anthers.

Gynoecium: Monocarpellary with 2-6 ovules surmounted by long filiform style which elongate with calyx tube and ends in a club shaped stigma among anthers, style curved and hairy.

Fruit: Immediately after fertilization, fruit appears at the end of pointed stalk like structure (gynophore) known as peg which elongates by means of intercalary meristem at the base of sessile ovary. Cells at tip of ovary become lignified and push the base of the stigma to one side forming a protective cap as peg enters the soil. The peg elongates and grows downwards penetrating the soil depth of 2-7 cm and as it loses its geotropism, the tip turns to the horizontal position and the ovary swells rapidly. Young peg is conical in shape, and the tip retains its shape until the maximum penetration of the soil is reached.



Mature fruit is structurally dehiscent but functionally indehiscent legume; oblong; 1-6 seeded; pericarp of mature fruit reticulate with 10 longitudinal ridges; reticulations are due to mechanical tissue below the vein in the hardened mesocarp; endocarp made of parenchymatous tissue

surrounding the developing seed which serves as storage tissue, collapses as pod mature eventually forming thin papery lining.

Seed: Mature seed elongated, cylindrical, or ovoid; white, pink red, purple and shades of brown; testa thin; contains no endosperm.

Pollination: Cleistogamy, hence self-pollination is the rule; insects visits the flowers, but out crossing is very rare.

FLOWERING

Depending on photoperiod, temperature and genotype flowering starts at about 25 days after emergence. The number of days required to first flowering reduces to 38 to 24 days when the daily mean temperature rises to 20-30°C in spreading-semi-spreading types while it drops from 35 to 24 days in Spanish-Valencias". The most prolific flowering occurs between 5 and 11 weeks after planting depending on the duration of cultivar, and the season with a high degree of first formed flowers producing mature fruits. Usually four to five stages of flowering can be observed.

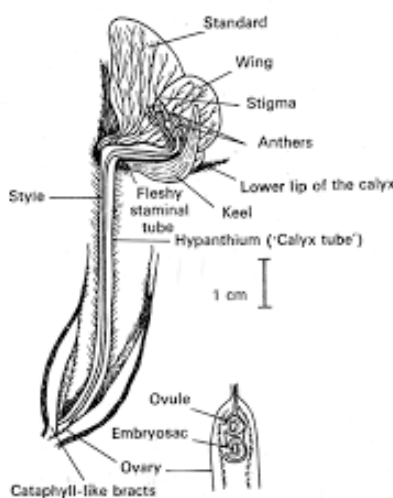
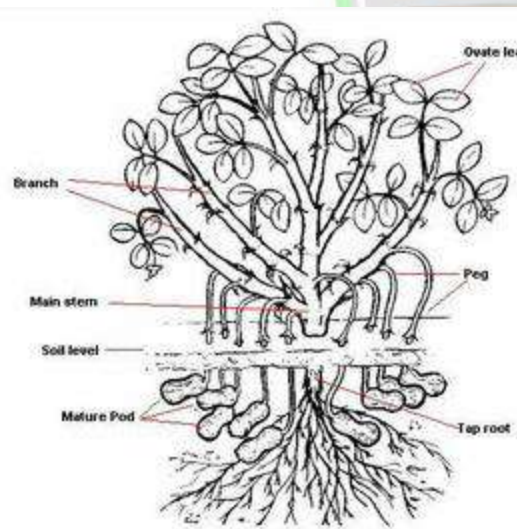
1. Very few flowers are produced in stage
2. rapid flowering in stage
3. A peak is reached at stage
4. A decline in the number of flowers at stage
5. In some genotypes there can be two peaks of flowering.

Very few flowers that are formed after the first and or second peaks of flowering produce mature fruits, unless early flowers are prevented from functioning normally due to some environmental stress. Groundnut produces more flowers than the plant can sustain to develop in to pods. About 40% of flowers fail to develop from the outset, while another 40% produce only pegs. Less than 20% of flowers only produce mature fruits. Genotypes which flower early and produce most of the flowers during first two weeks of the flowering period produce greater number of pods. A day before anthesis, the flower bud is 6-10 mm long. During day time the hypanthium elongates slowly and the buds grow to 10-20 mm long. The elongation is faster during the night and at the time of anthesis the buds are about 50-70 mm long. Flower buds generally open at the beginning of the light period; it may be delayed in cold or wet weather. The dehiscence of anthers takes place 7-8 hours before the flower opens or some times much later. Generally it takes place 1 hour before opening. Similarly the stigma is reported to be receptive

from 24 hours before to 12 hours after the opening of the flower, but generally it is receptive only a few hours before anthesis. The pollen tube grows at the rate of about 1 cm per hour resulting in fertilization 5-6 hours after pollination.

PEG FORMATION:

The developing ovary pierces through the floral parts to reveal an elongating peg, a green stalk like structure which is botanically a 'carophore' or 'gynophore' and starts growing (elongating) geotropically. The peg carries the fertilized the ovule at its tip. The numerous plastids that develop after fertilization in the epidermal wall of the peg were found responsible for its positive geotropic movement. The peg becomes diageotropic after penetrating the soil and ceases to elongate due to the formation of auxins formed in its distal portion. The diageotropism is such that the ovules are always located on the upper wall of the pod with the pod tip pointing away from the plant. Differences between cultivars in the depth at which pod are formed have also been reported. The normal podding zone is 4-7 cm below soil surface. The optimum temperature in podding zone is about 31-33°C. Lower soil temperature around 23°C increases number of pods and pod weight but increases filling duration thus increasing maturity. It takes about 60 days from the time of fertilization to full maturity.



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THE ROLE OF MICRO BIOMES IN ENHANCING SEED VIGOUR AND PRODUCTIVITY

Article ID: AG-VO5-I05-44**Pravina K^{1*} and Sujatha K²**

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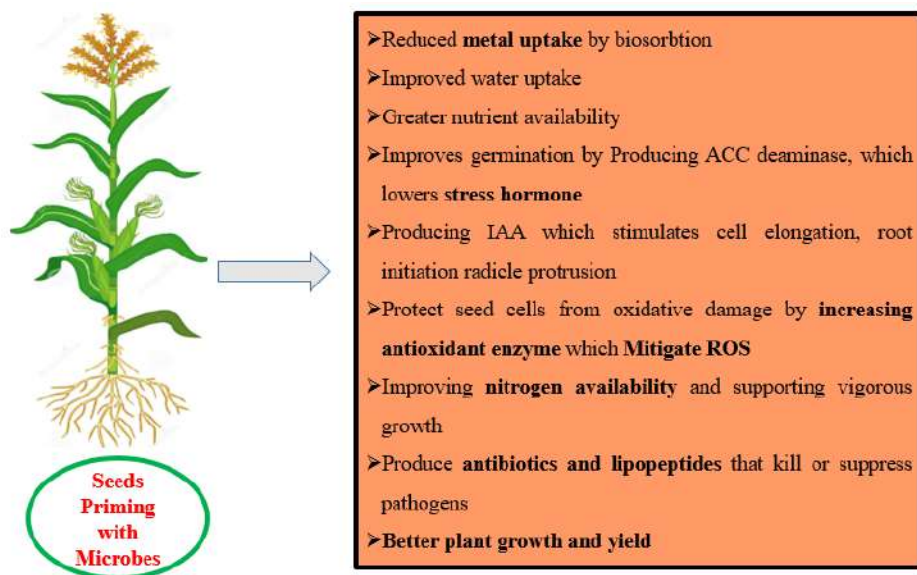
Introduction

The plant microbiome, a dynamic and diverse community of microorganisms associated with seeds and soil, plays a vital role in plant development from germination to maturity. Plant microbiomes are tiny organisms (mainly bacteria and fungi) which are live on and inside seeds, roots, leaves and stems. These microbes are beneficial and they help plants grow better, especially during seed germination, early growth and even at harvest. Advances in metagenomics and microbial ecology have enabled scientists to identify key microbial taxa and functions that support plant growth, offering eco-friendly solutions for agricultural productivity. This paper synthesizes current understanding of the mechanisms through which microbiomes affect these developmental stages, explores beneficial microbial groups and their applications and highlights future directions in microbiome engineering and sustainable agriculture.

Microbial Seed Priming (Bio-priming)

Bio-priming is a technique where seeds are treated with beneficial microbes before sowing. These microbes colonize the seed surface or enter the seed tissues and help to enhance germination, vigour, and stress tolerance. During priming, microbes are attached and colonize the seed coat or enter into the seed endosperm/embryo. This colonization ensures early establishment of microbe-plant interaction. Under salinity or cold stress microbes like *Trichoderma harzianum* improves germination by producing ACC deaminase, which lowers stress hormone ethylene levels and protect seed cells from oxidative damage by increasing

antioxidant enzyme activities (e.g., SOD, CAT) and help to maintain membrane integrity (Harman et al., 2004). *Bacillus subtilis* helps to enhance the germination by producing IAA which stimulates cell elongation, root initiation radicle protrusion (Kloepper et al., 2004) and both microbes produce antibiotics and lipopeptides that kill or suppress pathogens. It compete for space and nutrients, preventing colonization by harmful fungi and bacteria and Induce Systemic Resistance (ISR) in the seedling, boosting its internal immune response.



Microbiome on Seed Germination Mechanism

Hormone Production: *Bacillus* spp., *Azospirillum* spp., *Pseudomonas* spp. are synthesize plant growth-promoting hormones, primarily gibberellins (GAs) and cytokinins. Gibberellins break seed dormancy by stimulating the synthesis of hydrolytic enzymes (like α -amylase) in the aleurone layer of cereal seeds. These enzymes mobilize stored starch into sugars, supplying energy to embryo growth and cytokinins promote cell division in the embryonic tissues and enhance nutrient mobilization to the growing radicle and plumule. Which results in faster and more synchronized germination, improved seedling vigor (Gogoi & Deka, 2021).

Enzyme Secretion: *Paenibacillus*, *Bacillus*, *Trichoderma* spp. are secrete cell wall-degrading enzymes, such as cellulases helps to break down cellulose in the seed coat. Pectinases enzymes degrade the pectin in the middle lamella of seed coat cells. This softens or loosens the seed coat, reducing physical resistance to radicle protrusion which *result in* enhanced water uptake (imbibition), easier radicle emergence, and quicker germination (Barret et al., 2015).

ROS mitigation and antioxidant induction: Germination is often associated with the generation of reactive oxygen species (ROS), such as hydrogen peroxide (H_2O_2) and superoxide (O_2^-). Moderate ROS levels are needed for cell wall loosening and signaling, but excess ROS damages DNA, proteins, and lipids. Microbes like *Pseudomonas fluorescens* and *Bacillus subtilis* stimulate the plant's antioxidant defense system, enhancing activity of enzymes like Superoxide dismutase (SOD), Catalase (CAT) and Ascorbate peroxidase (APX) (Rajendran et al., 2021). Some microbes also produce antioxidant molecules themselves (e.g., glutathione, phenolics) which is result in protection of embryonic tissues, improved metabolic balance and higher germination success.

Microbial influence on seedling vigour mechanism

Root Colonization and Microbial Recruitment: As seedlings emerge, their roots begin to exude a variety of organic compounds such as sugars, amino acids, organic acids and phenolics collectively known as root exudates. These exudates act as chemical signals and food sources, shaping the microbial community structure in the rhizosphere (Sasse et al., 2018). Beneficial microbes recruited through this process contribute to early seedling development via several mechanisms which is Indole-3-Acetic Acid (IAA) Production, 1-Aminocyclopropane-1-Carboxylate (ACC) Deaminase Activity and Siderophore Production which result in better root development (Spaepen et al., 2007).

Nutrient Acquisition and Root Development: Plant growth-promoting rhizobacteria (PGPR) and mycorrhizal fungi play a crucial role in enhancing nutrient uptake during early seedling development. Nitrogen-fixing bacteria such as rhizobium and azospirillum convert atmospheric nitrogen into forms accessible to plants, thereby improving nitrogen availability and supporting vigorous growth (Bashan et al., 2004). In parallel, phosphate-solubilizing bacteria like *Pseudomonas fluorescens* and *Bacillus megaterium* release organic acids that mobilize insoluble phosphorus compounds, making this essential nutrient readily available for plant uptake (Rodríguez & Fraga, 1999). Together, these microbial interactions promote the development of stronger root systems and significantly enhance seedling establishment.

Contribution to crop productivity mechanism

Beneficial microbes significantly contribute to crop productivity through direct growth promotion. To begin with, certain microbial species can directly stimulate plant growth by releasing volatile organic compounds (VOCs). These VOCs act like airborne plant hormones,

triggering growth-related gene expression in plants even without direct contact. For example, a study by Ryu et al. (2003) showed that VOCs emitted by rhizobacteria like *Bacillus subtilis* enhanced plant growth by stimulating shoot and root development. Beyond VOCs, microbes also play an essential role in supporting nutrient cycling and photosynthesis. Microorganisms such as *azospirillum*, *rhizobium* and *pseudomonas* help convert atmospheric nitrogen into a usable form, solubilize phosphorus, and produce siderophores that improve iron availability to plants. As reported by Compant et al. (2010), these processes result in healthier plants with higher chlorophyll content and better photosynthetic efficiency, which naturally supports higher biomass and grain production increase 25–30% in maize yield (Woo et al., 2006).

This improvement is attributed to *Trichoderma*'s ability to colonize the root surface, enhance nutrient uptake and protect against root pathogens. Likewise, under stressful environments such as saline soils, salt-tolerant plant growth-promoting rhizobacteria (PGPR) have shown remarkable potential. Egamberdieva et al. (2017) found that halotolerant PGPR improved rice yield significantly under salinity stress. These microbes help the plants adapt to salt stress by producing ACC deaminase (which reduces ethylene stress), improving osmotic balance and enhancing root development. One of the most exciting developments is the creation of **synthetic microbial communities** (also called SynComs). These are carefully selected consortia of beneficial microbes that work together to promote plant growth, suppress diseases, and improve resilience to environmental stress. Scientists are designing these microbial communities to mimic the natural microbiome of healthy plants with enhanced or targeted functions. Once developed, these SynComs can be applied directly to seeds or soil to **boost crop productivity and health** in a predictable and consistent manner.

Conclusion

Plant-associated microbiomes are integral to the success of early plant development and ultimate crop productivity. Understanding and leveraging microbial functions offer promising avenues for sustainable agriculture. Future work should focus on stable formulations, host specificity, and field performance of microbial consortia.

Challenges

- Environmental variability affecting microbial survival.
- Lack of standardization and regulatory clarity.
- Need for host-genotype–micro biome compatibility (Compant et al., 2019).



Future perspectives

In parallel, advancements are being made in seed coating technologies, where seeds are embedded with beneficial microbes during processing. These microbial seed coatings offer a dual benefit: they stimulate early growth and protect seedlings from pathogens and abiotic stress, acting as a natural alternative to chemical fertilizers and pesticides. This approach is especially promising because it allows precise delivery of microbial inoculants right where they are needed—at the seed-soil interface. With the integration of genomics, bioinformatics, and microbial ecology, the future also points toward customized micro biomes for specific crops and environments. Farmers may one day be able to select microbial formulations tailored to their local soil, climate, and crop type, leading to precision micro biome management in agriculture. Ultimately, these innovations aim to make farming more ecological, efficient, and resilient, reducing dependency on synthetic inputs while maintaining or even increasing yield.



BOTANICA OF SOYBEAN

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Introduction

Soybean (*Glycine max* L. Merr.) belongs to the legume family Fabaceae and includes more than 40 species. Soy is an annual herbaceous plant with a height ranging from 25 to 200 cm. The human body's need for protein can mainly come from soybean meal as it contains up to 52% protein, 25% oil, and various vitamins. The soybean is one of the richest and cheapest sources of protein and is a staple in the diets of people and animals in numerous parts of the world. The seed contains 17 percent oil and 63 percent meal, 50 percent of which is protein. Because soybeans contain no starch, they are a good source of protein for diabetics. In East Asia and elsewhere, the bean is extensively consumed in the forms of soy milk, a whitish liquid suspension, and tofu, a curd somewhat resembling cottage cheese. Soy sauce, a salty brown liquid, is produced from crushed soybeans and wheat that undergo yeast fermentation in salt water for six months to a year or more; it is a ubiquitous ingredient in Asian cooking. Other fermented soy foods include tempeh, miso, and fermented bean paste. The soybean, soy bean, or soya bean (*Glycine max*) is a species of legume native to East Asia, widely grown for its edible bean, which has numerous uses.

Traditional unfermented food uses of soybeans include soy milk, from which tofu and tofu skin are made. Fermented soy foods include soy sauce, fermented bean paste, nattō, and tempeh. Fat-free (defatted) soybean meal is a significant and cheap source of protein for animal feeds and many packaged meals. For example, soybean products, such

as textured vegetable protein (TVP), are ingredients in many meat and dairy substitutes. Soybeans contain significant amounts of phytic acid, dietary minerals and B vitamins. Soy vegetable oil, used in food and industrial applications, is another product of processing the soybean crop. Soybean is a common protein source in feed for farm animals that in turn yield animal protein for human consumption. Soybean is a potentially important plant, ensuring the country's food security. Given the higher protein and oil contents in its seed, it is grown in 122 million ha in more than 20 countries worldwide. Soybean has the second largest planted area in the world, being the fourth most vital crop after wheat, rice, and corn. The leading countries growing it are Brazil (34 million ha), the USA (31 million ha), Argentina (18 million ha), India (11 million ha), and China (nine million ha).

TAXONOMY AND CLASSIFICATION:

The genus *Glycine* Willd. is a member of family Leguminosae, subfamily Papilionoideae, and tribe Phaseolae. The Phaseolae is the most economically important tribe of Leguminosae. *Glycine* has a confused taxonomic history from its inception. The name *Glycine* was first introduced by Linnaeus in the first edition of his *Genera Plantarum*. *Glycine* is derived from the Greek *Glykus* and probably refers to sweet tubers produced by *G. apios*, which he classified in this genus. Linnaeus listed eight *Glycine* species in the *Species Plantarum* of 1759. All of these were subsequently moved to other genera. Soybean was described by Linnaeus both as *Phaseolus max*, based on the specimens he saw and *Dolichos soja* based upon the description of other writers. Later when he obtained the seeds of *D. soja* and grew them, he realized that both *P. max* and *D. soja* were the same plant. Since then correct nomenclature of the soybean has been the subject of much debate. Currently the combination *G. max* proposed by Merrill in 1917 is widely accepted. Bentham (1865) arranged genus *Glycine* into three sections containing eleven species: *Leptolobium*, which comprised 6 species of Australian origin; *Johnia*, which comprised sole species of African and Asian origin; and *Soja*, which included cultivated soybean named by him as *Glycine soja*. Hermann (1962) published a revision of genus *Glycine* and its allies.

According to his classification genus *Glycine* consisted of three subgenera: (i) *Leptocytus* (Benth.) F.J. Herm. with six Australian species; (ii) *Glycine*, which included complex from Southeast Asia and Africa; and (iii) *Soja* (Moench) F.J. Herm., which comprised soybean and its wild annual counterpart described as *G. ussuriensis* by Regel and Maack (1861). Verdcourt (1966) revised this classification putting species earlier included in subgenus

Leptocytus, in subgenus Glycine. He reclassified subgenus Glycine as Bracteata and renamed the only species *G. javanica* of erstwhile subgenus Glycine as *G. weightii*. Verdcourt (1970) proposed that wild annual relative of soybean be designated *G. soja* as described by von Siebold and Zuccarini (1846) since it predates nomenclature *G. ussuriensis* of Regel and Maack (1861). The genus Glycine as currently delimited is divided into two subgenera Glycine and Soja. According to Hymowitz (2004) the subgenus Glycine comprises 22 wild perennial species (Table 1). The subgenus Soja includes *G. max* (L.) Merrill and its wild annual counterpart *G. soja* Sieb. and Zucc. The subgenus Soja contains in addition, a form known as *G. gracilis*, which is somewhat intermediate in morphology between *G. max* and *G. soja*. Hermann (1962) considered *G. gracilis* a form of *G. max* with some *G. soja* genes.

Table 1. List of species in the genus Glycine and distribution as of January 2002

Genus	Distribution
Subgenus Glycine	
<i>G. albicans</i> Tind. & Craven	Australia
<i>G. aphyonota</i> B. Pfeil	Australia
<i>G. arenaria</i> Tind.	Australia
<i>G. argyrea</i> Tind.	Australia
<i>G. canescens</i> F.J. Herm.	Australia
<i>G. clandestina</i> Wendl.	Australia
<i>G. curvata</i> Tind.	Australia
<i>G. cyrtoloba</i> Tind.	Australia
<i>G. dolichocarpa</i> Tateishi and Ohashi	Taiwan
<i>G. falcata</i> Benth.	Australia
<i>G. hirticaulis</i> Tind. & Craven	Australia
<i>G. lactovirens</i> Tind. & Craven	Australia
<i>G. latifolia</i> (Benth.) Newell & Hymowitz	Australia
<i>G. latrobeana</i> (Meissn.) Benth.	Australia
<i>G. microphylla</i> (Benth.) Tind.	Australia
<i>G. peratosa</i> B. Pfeil & Tind.	Australia
<i>G. pindinica</i> Tind. & Craven	Australia

<i>G. pullenii</i> B. Pfeil, Tind. & Craven	Australia
<i>G. rubiginosa</i> Tind. & B. Pfeil	Australia
<i>G. stenophita</i> B. Pfeil & Tind.	Australia
<i>G. tabacina</i> (Labill.) Benth.	Australia, West Central and South Pacific Islands
<i>G. tomentella</i> Hayata	Australia, Papua New Guinea, Indonesia, Philippines, Taiwan
Subgenus Soja	China, Russia, Taiwan, Japan, Korea (wild soybean)
<i>G. soja</i> Sieb. & Zucc.	
<i>G max</i> (L.) Merrill	Cultigen (soybean)

ORIGIN AND DOMESTICATION:

The place of origin of the cultivated form of soybean is still argued though Piper and Morse (1923) reported it to be a native of eastern Asia. According to them, *G. soja*, the progenitor of *G max* was known to occur in China, Manchuria, and Korea. Fukuda (1933) argued that Manchuria is the center of origin as: (i) *G. gracilis*, a closely related species is distributed widely in Manchuria; (ii) numerous soybean varieties are grown in Manchuria; and (iii) many of the varieties have primitive characteristics. Vavilov (1949/50) considered Central Western China as the center of origin for soybean. Nagata (1959, 1960) indicates that the center of origin was most probably China proper, especially in North and Central China. According to him, the cultivated soybean (*G max*) has originated from its ancestor *G. soja*, which is found wild in China, Korea, Manchuria, Taiwan, and Japan, throughout the Yangtze River valley, the Northeastern Provinces of China and the adjacent areas of USSR. The Yellow River region in China is generally considered as origin center of soybean based on the existence of a great number of wild soybeans and the earliest record of soybean in China (Hymowitz and Kaizuma, 1981; Wang and Wang, 1992). More recently, the real picture of origin of genus *Glycine* is depicted by Hymowitz (2004).

The wild relative of *G. max* was a rambling plant, growing close to the ground. Sometime around the 11th century BC, farmers in the winter wheat-growing regions of Manchurian China encouraged the recumbent wild legume to grow upright. The enthusiasm of Chinese farmers for the soybean was manifested in the names they bestowed on the crop's many varieties: Great Treasure, Brings Happiness, Yellow Jewel, and Heaven's Bird. After three millennia of breeding

and plant selection, today's soybean plants typically stand three feet high and three feet wide, bearing sixty to eighty pods. of three beans each. The best evidence available on the antiquity of the soybean has been found from analysis of the picot-graph 'Shu' for the soybean found in the Book of Odess and Bronze inscriptions. These evidences provide a clue that the process of domestication could have undergone by the soybean during the Shang Dynasty which preceded the Chan Dynasty, or even earlier. Hu (1963) reported that the cultigen soybean (*G max*) appears to be domesticated by the farmers in the eastern half of northern China during the dynasty (1550-1027 BC) or perhaps earlier. Experimental studies on the time taken for a crop to respond to selection pressures under domestication to the level of refinement when it is readily accepted by others outside its area of natural occurrence gained importance only a few decades ago (Oka and Morishima, 1971). Linguistic, geographical, and historical evidences suggest that the soybean emerged as a domesticate around the 11th century BC in the eastern half of north China. Domestication is a process of trial and error and not an event. In the case of the soybean, this process probably took place during the Shang dynasty (c. 1700- 1100 BC) or perhaps earlier. By the first century AD the soybean probably reached central and south China, as well as peninsular Korea. The movement of the soybean within the primary gene center is associated with the development, consolidation of territories, and degeneration of Chinese dynasties.

BOTANICAL DESCRIPTION:

Habitat: Grown in areas where the summer is hot and rather damp; withstand excessive heat or severe winters; grown on a wide range of soils.

Habit: Erect, bushy pubescent annual with grey hairs on all parts of the plants; some are prostrate and twining, a tendency which increases with shade; determinate cultivars develop terminal inflorescence; indeterminate cultivars shows axillary inflorescence.

Roots: Taproot, nodules small spherical sometimes lobed.

Stem: Branched stem reaching more than 2 m.

Leaves: The primary leaves do not normally develop unless tip damaged. Alternate, trifoliate, rarely five foliage; petiole long narrow, cylindrical; stipules, small lanceolate, stipels minute; leaflets ovate to lanceolate, usually palea green in colour, base rounded; apex acute or obtuse; lateral leaflets often slightly oblique; most cultivars drop leaves when pods begin to mature.

Inflorescence: Short clustered axillary raceme; terminal if determinate type.

Flowers: Small, bracteoles two, ovate and acute.

Calyx: Hairy, persistent, united for half-length with two upper and three lower lobes.

Corolla: White or lilac; standard ovate, emarginated (notched at the extremity); wings narrow, obovate; keel shorter than wings, not fused along upper surface.



Androecium: Stamens monadelphous; vexillary stamens free at the base; anthers uniform, globose.

Gynoecium: Hairy sessile, few ovuled, style curved, glabrous, stigma capitate.

Fruit: Pod; borne in cluster on short stalks; pale yellow, grey or black; slightly curved.

Seed: Globose; testa straw yellow; green, brown or black or blotched and mottled in combination of these colours, hilum small; cotyledon yellow or green.

Pollination: Self-pollination is the rule. Flowers open in the early morning and pollen is shed just before or at the time of opening and is shed directly onto the stigma. Bees and other insects visit flowers so that cross-pollination can take place, but is usually less than one per cent.

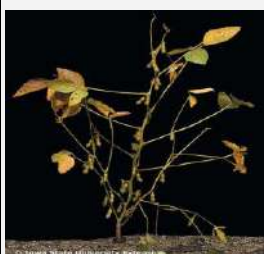
EVOLUTION OF THE *Glycine* GENOME:

Basic chromosome number $x=10$ has been proposed for *G. max*. Based on this proposal, Singh hypothesized a putative ancestor with $2n=20$ chromosomes for the genus *Glycine* and carrying at least one pair of nucleolus organizer regions (NORs). Although such a progenitor is currently unknown, it would be most likely found in Southeast Asia (Cambodia, Laos, and Vietnam). Whether tetraploidization ($2n=4x=40$) involved auto-(spontaneous chromosomes doubling) or allo- (interspecific hybridization followed by chromosome doubling) polyploidy of the progenitor species and whether it occurred prior to dissemination or after, cannot be substantiated experimentally, because center of origin of the progenitor of the genus *Glycine* is unknown.

PHENOLOGY AND GROWTH STAGES:

Vegetative Stages	Growth Stages	Growth Stages Details
	VE	Emergence - cotyledons have been pulled through the soil surface
	VC	Unrolled unifoliate leaves - unfolding of the unifoliate leaves
	V1	First trifoliate - one set of unfolded trifoliate leaves

	V2	Second trifoliolate - two sets of unfolded trifoliolate leaves
	V4	Fourth trifoliolate - four unfolded trifoliolate leaves
	V(n)	nth trifoliolate - V stages continue with the unfolding of trifoliolate leaves. The final number of trifoliolate's depends on the soybean variety and the environmental conditions
Reproductive Stages	Growth Stages	Growth Stages Details
	R1	Beginning flowering - plants have at least one flower on any node
	R2	Full flowering - there is an open flower at one of the two uppermost nodes
	R3	Beginning pod - pods are 3/16 inch (5 mm) at one of the four uppermost nodes

	R4	Full pod - pods are 3/4 inch (2 cm) at one of the four uppermost nodes
	R5	Beginning seed - seed is 1/8 inch long (3 mm) long in the pod at one of the four uppermost nodes on the main stem
	R6	Full seed - pod containing a green seed that fills the pod capacity at one of the four uppermost nodes on the main stem
	R7	Beginning maturity - one normal pod on the main stem has reached it's mature pod color
	R8	Full maturity - 95% of the pods have reached their full mature color

The progenitor of the wild perennial species of the *Glycine* radiated out into several morphotypes depending on the growing conditions in the Australian subcontinent. These species have never been domesticated and remained as wild perennials. In contrast, the pathway of migration from a common progenitor to China is assumed as: wild perennial ($2n=4x=40$; unknown and may be extinct) → wild annual ($2n=4x=40$; *G. soja*) → soybean ($2n=4x=40$; *G. max*). All species of the genus *Glycine* exhibit diploid-like meiosis and are inbreeders.

Allopolyploidization probably played a key role in the speciation of the genus *Glycine*. This implies that the 40- chromosome *Glycine* species and 80- chromosome *G. tabacina* and *G. tomentella* are allotetraploid and allooctoploid, respectively. Meiotic pairing in haploid ($2n=20$; range 0II-5II) soybean and in interspecific hybrids, fluorescent in situ hybridization (FISH), and molecular studies elucidate that soybean is of tetraploid origin.

Conclusion

Soybeans are a significant global crop due to their high protein and oil content, and their ability to fix atmospheric nitrogen, enriching the soil. They are an important food source, animal feed, and a source of oil used in various industries. Soybeans are also beneficial for crop diversification and improving soil fertility through crop rotation. Soybean plays a vital role in improving soil fertility, which demands focus, with its use in crop rotation showing excellent results. Soybean absorbs pure atmospheric nitrogen through nitrogen-fixing bacteria found in their root nodules and enriches the soil. During the growing period, the soybean plants keep a certain amount of nitrogen for themselves and the following crop. It also improves the composition of the soil and enhances the activity of biological and physiological processes. In the soybean fields, the soil microflora improves, creating a natural and ecological system in the ground. Additionally, creating a favorable environment benefits the life of earthworms, rhizobial bacteria, and other beneficial organisms.

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GERMPLASM EVALUATION

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Introduction

The germplasm collection is a collection of large number of genotypes of a crop species and its wild relatives. On other words it is the sum total of hereditary or genes present in a species. Therefore germplasm consists of the following five types of materials. Germplasm collections are also known as 'gene banks' or 'gene pool' or 'world collection'.

GERMPLASM EVALUATION

Germplasm evaluation refers to the assessment and characterization of plant genetic resources such as seeds, plants, or tissues to identify their valuable traits and potential uses. The goal is to;

1. Documentation and conserve genetic diversity.
2. Identify desirable traits (ex: disease resistance, drought tolerance).
3. Develop new crop varieties or improve existing ones.
4. Enhance breeding programs.
5. Support plant improvement and research.

TECHNIQUES INCLUDING

1. Phenotypic characterization (observing plant characteristics)
2. Genotypic characterization (analysing DNA markers)
3. Performance testing (evaluating plants in different environments)
4. Molecular marker analysis
5. Chemical analysis (ex: for nutritional content)

GERMPLASM EVALUATION IS CRUCIAL FOR

- Preserving crop diversity
- Ensuring food security
- Addressing climate change
- Improving crop yields and quality
- Supporting sustainable agriculture practices

DEFINITION

It deals with the assessing of the agronomic potential of an accession including quality parameters and response to various abiotic and biotic stresses.

- ❖ Evaluation of germplasm resources is necessary to identify the appropriate germplasm with a target trait for their further utilization.
- ❖ Evaluation of germplasm is a multi-disciplinary approach and it should be done in collaborative mode involving germplasm curator, plant breeder, physiologist, pathologist, entomologist, biochemist etc.
- ❖ Proper plant spacing, fertilizer application, weeding, irrigation, plant protection measures need to be followed.
- ❖ The number and row length should be more for the cross-pollinated species than those for self-pollinated ones.
- ❖ The observations should be recorded on the plants from the middle row to avoid the border effects.
- ❖ After evaluation, the promising accessions should be further validated through multi-locational, multi-season and multi-year evaluations.
- ❖ Evaluation trails should be carried out in at least three diverse environments to minimize Genotype X Environment (GVE) interaction.

EVALUATION FOR BIOTIC STRESSES

- ❖ A particular race/strain/line type within a specific location does not guarantee its resistance response in other locations may vary depending upon the agro-meteorological conditions.
- ❖ Therefore , screening of germplasm for biotic stresses should be accompanied with identification race/strain/biotype of the pest and pathogens existing at that particular locations. These four factors—susceptible host, violent pathogen, environment, and

time—are collectively referred to as the ‘Disease Quadrangle.’

- ❖ For recording of the observations on fungal, bacterial, and viral diseases, the standard evaluation system (SES) scale should be followed.
- ❖ For recording of the data on defoliators, the percentage of infestation in each accession should be recorded.
- ❖ In case of sucking insect pests, the number of insects per unit plant/leaves/inflorescence should be counted.

EVALUATION FOR ABIOTIC STRESS

- ❖ Preliminary screening/phenotyping should be done for one year with a large number of accessions under field conditions. To narrow down the large number of accessions, it should be done once a year with a large number of accessions under field conditions peculiar to the stress under study.
- ❖ Evaluation of germplasm for tolerance to different abiotic stresses is to be carried out under well-defined controlled conditions so that the optimum stress can be imposed at the desired stage.
- ❖ Evaluation for light and temperature stresses should be carried out under phytotron facility.
- ❖ Evaluation for drought tolerance should be undertaken in drought plots with rain out shelters and with well defined moisture conditions.
- ❖ Microplots with well defined electrical conductivity including specific salt/ions should be used for evaluating germplasm under saline/alkaline conditions.
- ❖ Standard checks identified for specific abiotic stress should be used for proper comparison of the germplasm.
- ❖ Controlled conditions should be imposed at the desired stage so that the optimum stress can be applied.

EVALUATION FOR QUALITY PARAMETERS

- ❖ Quality evaluation plays an important role in view of nutritional and health security.
- ❖ Quality traits, like oil, fatty acids, proteins, phenols, sugars, amino acids, vitamins, minerals, and others, should be evaluated.
- ❖ Properly labelled and packed material containing complete experimental details along with passport information should be made available for quality analysis.



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BIOACCUMULATION AND BIOMAGNIFICATION: THE SUBTLE PROCESSES THAT QUESTION OUR SURVIVAL

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Introduction

The earth offers a biological environment within which the living organisms range from *Mycoplasma genitalium* (the smallest living organism that can reproduce) to *Armillaria solidipes* (the largest living organism by mass and size) thrive for centuries. Every organism is formed through the growth and multiplication of the basic units of life, cells. But what happens when a highly toxic substance enters an organism, even at the cellular level? This question can be approached from two perspectives: natural processes and artificial interventions which intensifies natural processes. Regardless of the approach, both ultimately lead to two key outcomes called bioaccumulation and biomagnification. As the name signifies, bioaccumulation is the process of the gradual acquisition of pollutants or toxins within the body of a living organism over time whereas biomagnification is the process of prolonged increase in the concentration of bioaccumulative and bioconcentrative pollutants or toxins, as they move through successive trophic levels of the food chain and food web.

Occurrence

As per studies and research, the causes of biomagnification include Persistent Organic Pollutants (POPs), Polychlorinated Biphenyls (PCBs) and pesticides like DDT, heavy metals like mercury and cadmium. As smaller organisms are consumed by larger ones the concentration of these pollutants increases, leading to higher concentrations in top predators that eventually result in biomagnification.

Anthropogenic Impact on Bioaccumulation and Biomagnification

The evolution of humans also resulted in the evolution of these processes. Industrialization and technological advancement have not only introduced new contaminants into aquatic ecosystems but also intensified the naturally occurring processes of bioaccumulation and biomagnification. This intensification occurs through the release of persistent and bioavailable toxicants that accumulate in aquatic food webs far beyond naturally occurring levels.

Mercury has become a major environmental toxin due to human-driven emissions. Recent studies have shown that anthropogenic sources such as coal combustion and gold mining significantly increase methylmercury concentrations in aquatic systems. Persistent compounds like Polyfluoroalkyl Substances (PFAS) did not exist in nature but now widely contaminate aquatic food webs due to industrial and consumer product waste. Human-generated micro plastics act as carriers for heavy metals and hydrophobic organic pollutants. These particles are readily ingested by aquatic organisms, increasing exposure to attached contaminants. Human activities such as urban runoff, industrial effluents, and fertilizer use have increased concentrations of Potentially Toxic Elements (PTEs) in rivers and estuaries. The rise of nanotechnology has introduced inorganic nanoparticles into aquaculture systems. These particles accumulate in organs of cultured species, presenting a new dimension to contaminant transfer.

Sources of the compounds

The aquatic environment is more vulnerable than terrestrial. According to the Food and Agriculture Organization (FAO, 2022) and the United Nations Environment Programme (UNEP, 2019), these pollutants include persistent organic pollutants (POPs), pesticides (e.g., DDT), etc. Lipid solubility, environmental persistence, and low degradability of these substances are some of the factors which enhance their retention in organism. As highlighted in the IPBES Global Assessment Report (2019) and the World Health Organization (WHO, 2010) reports on water pollution and ecosystem health, top predators such as large fish, marine mammals, and birds of prey accumulate the highest concentrations, posing severe risks to biodiversity and human health.

Harmful effects of bioaccumulation and biomagnification

Numerous studies have been conducted on the effects of the processes and their comprehensive results are as follows:

Neurological and Behavioral Disorders - Exposure to neurotoxic substances like methylmercury can impair neurological functions in aquatic species, leading to altered behavior, reduced feeding efficiency, and increased vulnerability to predators. Reproductive Impairments - Heavy metals such as cadmium and lead can disrupt endocrine functions leading to decreased fertility, altered sex ratios, and developmental abnormalities in offspring.

Growth and Developmental Issues - Accumulation of contaminants like copper and zinc can interfere with metabolic processes, resulting in stunted growth and morphological deformities in fish and invertebrates. Genotoxic Effects - Certain pollutants can cause DNA damage in aquatic organisms, leading to mutations, cancer, and impaired cellular functions.

Mortality and Population Decline - Persistent exposure to toxic substances can increase mortality rates and lead to population declines, especially in sensitive species. For example, tributyltin (TBT), once used in antifouling paints, caused significant population declines in non-target marine organisms due to its toxicity and bioaccumulative nature.

As humans are the apex predators who occupy the highest trophic level in the food chain, they are more prone to the processes, especially biomagnification. The health effects are highly lethal such as the neurotoxicity caused by the mercury (especially methyl mercury) damages the brain and neural development. Its symptoms include cognitive deficits, motor dysfunction, vision and speech impairments. The mercury also increases the risk of pregnancy as it crosses the placenta and affects fetal development.

Another common health issue is caused by Polychlorinated Biphenyls (PCBs) which are carcinogenic and lead to the disruption of the whole endocrine system which further results in the alteration of hormone levels especially in females as reported. PCBs also suppress immune function and impair reproductive health. Similar to PCBs, dioxins (having longer half-life) also cause cancer and reproductive and developmental problems that affect the immune response and hormonal production. Another cause comes from the intake of DDT which is stored in body fat and can be passed from mother to child via breast milk (as per the scientific experimental studies conducted in South African villages in 2012) and has been regarded as the probable human carcinogen. In comparison to the causes mentioned so far, the riskiest chemical that poses heavy damage to the health of humans is PFAS (Per- and Polyfluoroalkyl Substances), they are known as “forever chemicals” due to their resistance to environmental degradation and accumulation of

human bodies and responsible for the developmental effects in fetuses and infants, liver damage and immune system effects.

Most affected aquatic living organism

Although all the apex predators are affected, Orcas are considered highly susceptible to bioaccumulation and biomagnification compared to other top predators due to their position at the apex of the food chain, long lifespans, and the way they store fat, which accumulates contaminants for greater accumulation over time. While many top predators experience these effects, orcas often exhibit the highest levels of certain pollutants like PCBs in their tissues.

Study conducted by Central Pollution Control Board (CPCB) as a part of National Water Quality Monitoring Programme (NWMP), 2023 shows Probable Contaminated Sites (PCS) and Contaminated Sites (CS) across 21 states of India (as of 09 December 2022) which is explained in the following figure.

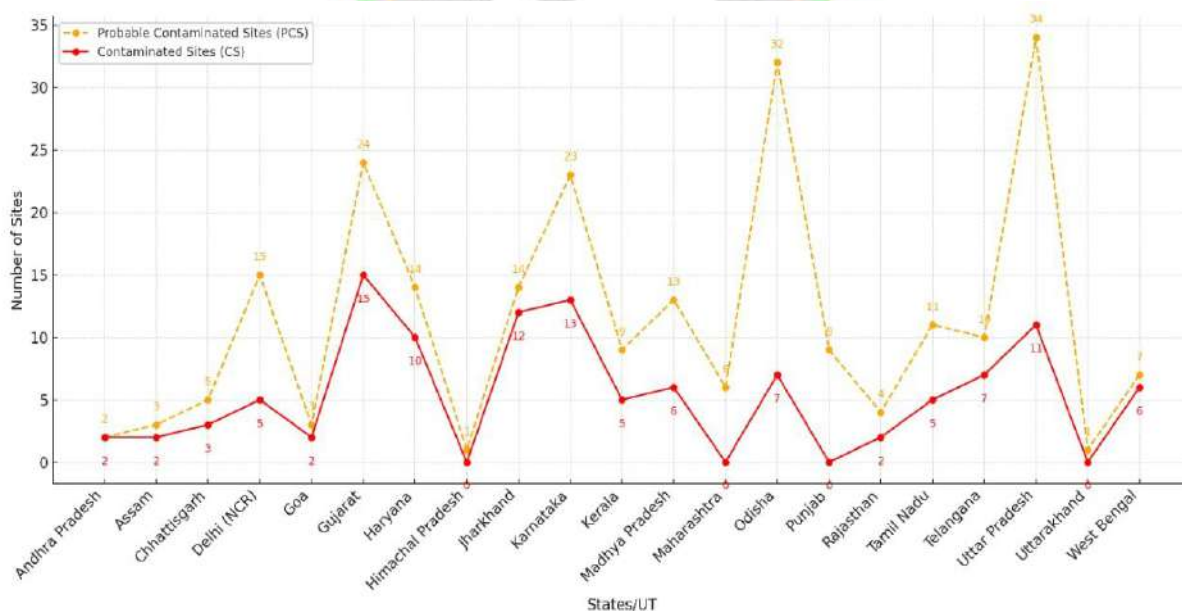


Figure: State-wise trend of probable and confirmed contaminated sites in India

Measures to protect ourselves

Although the processes became inevitable in this fast-paced world, human beings can restore ourselves and all other ecosystems around us. Here are the nine notable ways for the prevention:

- 1) Stringent regulations and regular government monitorization on the use of toxic chemicals used in industrial processes.

- 2) Stern and severe punishments for the usage of chemicals above the safety levels.
- 3) Adhering to the food safety regulations regarding Hazard Analysis and Critical Control Points (HACCP), especially in the fish processing industries.
- 4) Tests should be done to check the level of toxins in the fish and shellfish that are used for the preparation of processed fishery food products.
- 5) Control on the usage of chemical fertilizers for the growth of cultured fish and shellfish in aquaculture farms.
- 6) Organization of various awareness programs, symposiums, and seminars on the health risks of taking foods containing bioaccumulative toxins.
- 7) Follow the strategies introduced by the Ministry of Environment, Forest and Climate Change (MoEFCC) to combat water, air and land pollution.
- 8) Conduct toxicity tests periodically on the water bodies to keep tracking the level of heavy metals and toxins.
- 9) Adoption of organic aquaculture and agriculture that involve use of healthy biological fertilizers and manures instead of life-threatening chemicals.

Conclusion

These environmentally unfriendly processes are unsustainable. Bioaccumulation and biomagnification are indispensable but preventable. As the guardians of the earth, prevention is our responsibility. When toxins climb the food chain, they don't just poison water, they poison our futures. The pollutants that choked the gills of the fish will soon choke our throats. Urgent regulation, awareness, and sustainable practices are no longer choices, they are necessities for ecological survival and human health.

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BOUNDARY AND BUND PLANTATION UNDER AGROFORESTRY SYSTEM

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Introduction

Cultivation of tree species in association with agricultural crops is an age old practice but use of term agroforestry to it is quite recent (Tewari 1995). It is collective name for land use systems and technologies where woody perennials are deliberately used on the same management units as agricultural crops and / or animals in some form of spatial arrangement or temporal sequence (Lundgren and Raintree 1982). Now a days this systems of farming has gained the attention of researchers and planners because of its potentials in providing multiple ecosystems services apart from giving livelihood security to the rural poor.

Boundary Plantation

Boundary planting is often referred to as living fences or barrier planting because it involves planting trees along all types of boundaries. These can be the edges of property, agricultural fields, pastures, roads or any other place where fences might be located. Boundary planting also refers to trees planted for delimitation between two farms for live fencing, buffer between roads and farms, while providing timber, poles, fruits, fuelwood and services like wind breaks and soil erosion control.

Under boundary plantation large number of farmers adopted the practice of growing the trees species along their farm boundary to protect their farms. The major species are *Tectona grandis*, *Azadirachta indica*, *Terminalia bellerica*, *Dalbergia sissoo*, *Butea monosperma*, *Acacia catechu*, *Aegle marmelos*, *Tamarindus indica*, *Casuarina equisetifolia*, *Embllica officinalis*, *Acacia arabica*, *Ziziphus mauritiana* *Semecarpus anacardium* are grown on the boundary of the

field. The practice of growing multipurpose trees on the boundary of the field may be due to full fill the local needs of the people at subsistence level.

Bund plantation

Bund plantation is one of the agroforestry systems and most of the farmers adopted this practice growing trees along bunds namely *Tectona grandis*, and *Azadirachta indica*

Name of tree species suitable for bund Plantation and Boundary Plantation

Depending on the agroforestry systems, the common species used in boundary planting systems are *Eucalyptus* spp (Niligiri), *Tectona grandis* (Teak), *Thespesia populnea* (Huvarsi); *Albezia lebbek* (Bage), *Leucaena leucocephala* (Subabul), *Annona squamosa* (Seetaphal), Agarwood, *Gliricidia sepium*, bamboo, *Azadirachta indica* both in land demarcation, road stabilization and on-farm while in this system, *Eucalyptus* is exclusively used for road stabilization and rarely in land demarcation because it is highly competitive with associated crops.

The contour hedgerows are managed through pruning, thinning on the roads and in the demarcation. The products of management are used according to the decision of farmers, particularly for trees planted for demarcation. The branches pruned are used for example for firewood, and staking if they are strong enough to support beans or tomatoes. The use of leaves is not well established but many times are abandoned in the plantation. The trees planted for road stabilization are not used by the general population because it belongs to government. The management of those trees, in terms of thinning and pruning, is done by government. Once mature, trees are used for charcoal (*Eucalyptus* spp), timber and firewood (*Grevillea* and *Markhamia*). When young, the plants are also protected against damage from animals and human beings. The weeding is only done around young trees. Watering trees is not a common practice because the trees are accommodated with residual humidity in the soil. However, in the nursery, seedlings are watered.

Block plantation In many of places in Bangladesh, monoculture and block plantation of agar tree are very common (Rahman et al., 2015). But, there is hardly any information available regarding the block plantation (monoculture) in Northeast of India, even though few block plantations are seen to exist in the state like Tripura.

Boundary plantation Ha and Nghi (2011) reported that, agarwood tree is suitable for growing on field boundaries and even on borders of gardens, school compounds, office

compounds, parks and residential sites. Besides, agarwood tree has been successfully grown for strip planting along banks of ponds, tanks, canals and roads. In hilly areas / tillas, it can be planted on poor soils on hill slopes and tilla tops which can help in reducing soil erosion and land sliding (Shinde et al., 2019) caused by rushing water during rainy season (Ha and Nghi, 2011). Similar type of plantation can also be followed in this region.

Products and services

The major products provided in boundary trees planting are: fuel (firewood and charcoal), construction (timber and poles), bean stakes (branches) and indirect utilities for road stabilization, soil erosion control and other environmental services (including windbreak, shade, micro and macro climate regulation) and resilience to climate change.

Products

Fire wood: For many households, wood fuel is the primary utility derived from specific tree species they planted on boundary tree planting. Households in rural areas rely heavily on fuelwood for their energy needs for cooking meals. Note the objective of boundary trees planting is not to primarily satisfy firewood or charcoal needs, but is mainly used for land demarcation and road stabilization.

Timber/poles for construction: In boundary tree planting, trees like alnus, Grevillea, and eucalyptus can be used for timber when trees are mature.

Services

Soil erosion, windbreaks and shade: Boundary trees planting are essentially established for road stabilization and land delimitation. Besides these major services, they contribute to soil erosion control, wind breaks, shade and resilience to climate change.

Carbon sequestration: The boundary trees planting contribute to carbon sequestration through immobilization of carbon in the wood and reduce siltation for river or lakes in down stream

Products and Services	High	Medium	Low
Products			
Poles		Y	
Firewood		Y	
Timber		Y	

Services			
N ₂ Fixation and recycling		Y	
C sequestration		Y	
Soil erosion Control	Y		
Biodiversity conservation		Y	

Preferable characteristics of tree species to be promoted for Bund Plantation/ Boundary Plantation

The characteristics of boundary planting trees should be straight, noncompetitive, to have capacity to control soil erosion, improving soil fertility by leaf falling. Extraction of nutrients and water should be less so that the crop grown nearby should give better production. Boundary plantation is prominent feature of Indian agroforestry system as it very popular among the farmers due its less interference, ease in mechanization and demarcation of field boundaries. Plantation of *Eucalyptus* spp on the boundary and its suitable combination play a vital role in enhancement of better yield productivity, soil nutrient status and microbial population dynamics which plays a major role in nutrient cycling to maintain ecosystem. Due to shading effect and strong root system of *Eucalyptus*, which compete for moisture and nutrient with crops resulting grain yield near the tree lines was comparatively low. *Eucalyptus* is a cropland agroforestry tree species planted along with various annual crops like paddy, wheat, and cereals and other cash crops in farmers' lands either in scattered or in bund. *Eucalyptus globulus* trees are unpalatable to goats, sheep and cattle. Thus they have a distinct advantage as boundary planting in recommended inter-row spacing and are aligned east-west or north-south direction. In this environment, eucalypt boundaries produce a harvestable tree crop within four to five years after planting.

Management of tree component planted in Bund Plantation & Boundary Plantation

They are managed through pruning, thinning on the roads and in the demarcation. The products of management are used according to the decision of farmers, particularly for trees planted for demarcation. The branches pruned are used for example for firewood, and staking if they are strong enough to support beans or tomatoes. The use of leaves is not well established but

many times are abandoned in the plantation. When young, the plants are also protected against damage from animals and human beings. The weeding is only done around young trees. Watering trees is not a common practice because the trees are accommodated with residual humidity in the soil. Other practices are not generally adopted.

Economic returns

Effect of Bund Plantation & Boundary Plantation on crop yield

The outcome of yield depends upon tree spacing, density, type and nature of existing bund plantation and their shading effects.. The yield of crops increased with the increase in distance from the boundary.



Bamboo in field boundary



Medicinal shrubs (Pochotia) as live fencing surrounding vegetables/ field crops



Arecanut as boundary plantation surrounding mixed vegetables



Banana plantation at pond dyke

Trees under agroforestry besides providing the tree products, improves soil productivity through ecological and physico-chemical changes. Owing to the fast growth, deciduous nature,

marketing acceptability and successful intercropping, poplar cultivation has become popular among the farmers as a viable alternative to wheat-paddy rotation in north-western states of India. Poplar being a deciduous tree enters in dormancy during winter, therefore suited well to companion crop for ensuring food production and also enhance economic returns to the growers. This species has been grown by farmers as boundary or block plantation, which improves the physico-chemical properties of soil through addition of organic matter in the soil and provides alternate sources of income and employment to the rural poor. Leaf-fall at sowing poses physical barrier to seed germination and may affect the availability of nutrients/light to developing seedlings but addition of leaves changes the C: N ratio of the soil, which also influence the crop growth. Poplar being sensitive to water logging is unsuitable under rice based cropping system, but boundary plantation of poplar might be an option to continue traditional rotation of rice-wheat for the farmers who seem reluctant to leave the rotation because of assured market/minimum support price of the crops.

Crop yield

The distance from the boundary plantations have effect on crop growth. As the distance increases the growth also seems to be more. The visual observations made for rice crop growing with boundary plantation showed that the growth of the crop plants were poor as we moved towards the tree line in each direction from the centre of the field. The establishment of crop was poor near the tree line.

Distance of minimum 2.5 to 3 meter distance are necessary and plantation should be done in such a way that sunlight should not be hampered

- would the planting of trees shade the crops and prevent the crops from growing well ?
- would the planted saplings be grazed while these were still young, since cattle freely grazed on farmlands in the non-agricultural months ?
- would the roots of these trees intrude into the fields and disturb the growth of preferred crops ?
- would the effort of planting and caring for the trees be worth the investment ?

The recommended technique included

- establishing trees on bunds by transplanting nursery-grown saplings,
- regularly lopping off the trees of any height beyond 6 ft., and

- shearing off all the leaves from the entire tree well before the crop planting season each year.
- This eliminated the threat of crop-shading and ensured that the leaves were incorporated into the soil in time for planting of crops. Cassia Siamea was chosen as the main species to be planted on the bunds. Even though it did not have merits of high-quality leaf matter producer, it was not bad either as it was, by and large, non-browsable. Further, it was a nitrogen-fixating tree. Other species like Glyricidia were also planted in response to availability and farmers' preferences.
- Live fencing with woody perennials is need of our species suitable for the purpose need to be exempted from felling restrictions under state Agroforestry Policy

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AGROTOURISM IN INDIA: CULTIVATING RURAL PROSPERITY THROUGH TRAVEL AND TOURISM

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Introduction

India's travel and tourism industry continues to be a major engine of economic growth, ranking **7th among 185 countries** in terms of its total contribution to GDP in 2023. The sector contributed approximately **\$250 billion**, which is about **9.1% of the nation's GDP**, and generated close to **40 million jobs**, accounting for **8.6% of total employment**. Amidst this robust growth, a niche but rapidly emerging segment is **agrotourism** - a form of rural tourism centred on agricultural experiences.

Agrotourism is redefining how people engage with rural India. Beyond just sightseeing, it offers immersive experiences like farm stays, organic farming, traditional cooking, and learning about sustainable agriculture, all while supporting local farmers and artisans. A country with more than half of its population dependent on agriculture, agrotourism represents a powerful blend of **economic diversification, rural development, and cultural preservation**.

This growing sector is not only creating new revenue streams for farmers but also offering urban tourists a refreshing escape from fast-paced city life. As India strengthens its tourism infrastructure and promotes sustainable rural initiatives, agrotourism is poised to play a central role in bridging the gap between agriculture and mainstream tourism.

According to Mr. Pandurang Taware (ATDC, Pune) - "Agro-Tourism is that Agri-Business activity, when a native farmers or person of the area offers tours to their agriculture farm to allow a person to view them growing, harvesting, and processing locally grown foods, such as coconuts, pineapple, sugar cane, corn, or any agriculture produce the person would not

encounter in their city or home country. Often the farmers would provide a home-stay opportunity and education”. Agricultural Tourism is the Holidays concept of Visiting a working farm or any agricultural, horticultural, or agribusiness operations for the purpose of enjoyment, education, or active involvement in the activities of the farm or operation. Agro-tourism is a form of niche tourism that is considered a growth industry in many parts of the world.

Agrotourism in India gained momentum in **2004** with the establishment of the **Baramati Agri Tourism Center** in Maharashtra, spearheaded by **Pandurang Taware**, recognized as the **Father of Agrotourism**. His innovative approach earned him the **National Tourism Award** for the most innovative tourism product.



Building on this foundation, the **Agro Tourism Development Corporation (ATDC)** was established in **2005** to promote and develop agrotourism across Maharashtra. As of recent data, ATDC has expanded its reach to **328 agrotourism centers** across **30 districts** in the state. These centers have significantly contributed to rural development by providing farmers with an alternative source of income. The agrotourism model offers urban visitors authentic rural experiences, including farm stays, participation in agricultural activities, and exposure to local culture and cuisine. This initiative has not only enhanced farmers' livelihoods but also fostered sustainable tourism practices in the region.

Basic principle of Agro-tourism: (1) Have something for visitors to see - Animals, birds, farms ,festivals, cultural dress, rural games. (2) Have something for visitors to do - Participating in agricultural operations, swimming, bullock cart riding, camel riding, buffalo riding, cooking and participating in the rural games. (3) Have something for visitors to buy - Rural crafts, dress

materials, farm gate fresh agriculture products, processed foods are the few items which tourist can buy as memento for remembrance.

Why India is perfect for Agrotourism

India is uniquely positioned for agrotourism for several reasons:

- A deeply agrarian heritage: Agriculture is still the primary livelihood for more than 50% of Indians.
- Diverse climates and crops: From rice paddies to apple orchards, the variety is enormous.
- Rich cultural traditions: Each region offers its own food, music, festivals, and crafts.
- Growing urban interest: More urban Indians are seeking authentic rural escapes for relaxation and learning.

Popular Agrotourism Destinations in India

1. Baramati, Maharashtra: Often credited as the birthplace of organized agrotourism in India, Baramati's Agri Tourism Development Corporation (ATDC) offers everything from bullock cart rides to local dance performances. You can pick mangoes, learn how sugarcane is processed, and enjoy rustic Maharashtrian thalis.

2. Punjab – The Land of Five Rivers: In Punjab, you can stay in village homes, try your hand at tractor driving, enjoy traditional Punjabi food made from freshly harvested crops, and participate in folk dances like bhangra. The warmth of Punjabi hospitality makes it a favourite among NRIs and domestic tourists alike.

3. Kerala – God's Own Country: Kerala's spice plantations and organic farms are perfect for nature lovers. Walk through estates growing pepper, cardamom, and coffee, and experience the slower rhythms of a tropical rural life. Many tours also include cooking classes using locally grown ingredients.

4. Coorg, Karnataka: Known for its rolling coffee estates, Coorg offers luxurious yet grounded farm stays. Tourists can witness coffee harvesting, visit bee farms, and even learn about sustainable farming techniques.

5. Rajasthan – The Desert Farmer's Tale: Agrotourism in Rajasthan combines desert landscapes with cultural richness. Camel cart rides, pottery workshops, and traditional Rajasthani meals under the stars make it a sensory delight.

Benefits of Agrotourism in India

- Provides additional income for farmers



- Promotes rural development and job creation
- Preserves traditional culture, crafts, and farming practices
- Encourages sustainable and eco-friendly tourism
- Offers educational experiences for urban visitors
- Empowers women and youth in rural areas through tourism-related jobs

Challenges of Agrotourism in India

- Poor rural infrastructure and road connectivity
- Limited awareness and promotion of agrotourism
- Lack of training in hospitality and tourism management for farmers
- Inconsistent government support and regulatory hurdles
- Seasonal nature of tourism affects income stability
- Difficulty in maintaining modern amenities in remote areas

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www.agrotourism.in

BOTANICA OF CASTOR

Article ID: AG-VO5-I05-50**¹Adavi Lakshmi Nikhil., ²V. Krishnan., ¹A. Shivada, ¹V. B. Divyadarshini, ¹P. Sowmiya, ¹C.****S. Subash Chandra, ³M. K. Sakthi Anand, ¹K. Preetha and ¹R. Praveen**

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Introduction

Ricinus communis L. belongs to the Euphorbiaceae family and is mainly cultivated in tropical and subtropical regions worldwide. Its seeds contain high levels of toxic compounds, such as the ribosome-inactivating protein ricin and the alkaloid ricinine. *R. communis* is a xerophytic and heliophile plant that presents a deep taproot system, simple (i.e., lobed or unlobed but not separated into leaflets) and denticulate leaves, with great phenotypic variability in its morphological characteristics. Its phenotypic diversity is quite wide, with variations in growth habits, colour of the leaves, stem and seeds, and oil content. Additionally, it presents variation in plant size (shrub or tree height), annual or casually biennial cycle, and great variability in appearance and biometric parameters of the seeds. Some cultivars have annual average cycle of 150 days, which is more suitable for mechanical harvesting due to homogeneous maturation of the seeds. The long-cycle varieties (180 to 210 days) are better suited to tropical regions, and have increased tolerance to biotic and abiotic stresses, and therefore most recommended for producers using low-tech resources.

The castor plant (*Ricinus communis* L.), also called castor bean plant or castor oil plant, is a shrub or small tree cultivated in tropical and temperate regions for its seeds rich in an oil valued for its many industrial applications: lubricants (the Castrol automotive lubricant is a contraction of "castor oil"), hydraulic fluids, paints, coatings, inks, cold resistant plastics, waxes and polishes, nylon, pharmaceuticals, emollients, perfumes, etc). Castor oil was used for lighting

(though the smell is unpleasant), and in medicine as a purge or to treat sores. The castor plant is also an energy crop used to produce biodiesel). The extraction of castor oil yields a protein-rich by-product, called castor oil cake or castor oil meal. Another by-product is the castor seed hulls (or husks), a fibrous product. A major issue with *Ricinus communis* is the presence of toxic compounds in all the parts of the plant. In particular, castor seeds contain ricin, a lethal cytotoxin. While castor oil cake is valuable for animal feeding, it must be detoxified before use.

ORIGIN AND DISTRIBUTION:

The origin of *Ricinus communis* is debated due to its wide distribution since ancient times, and because of the rapidity of its establishment as a native plant. It may have originated in North-East Africa and it was grown for its oil in Egypt about 6000 years ago. Hooker (1890) is of opinion that though castor bean is cultivated throughout India, it is indigenous to Africa.

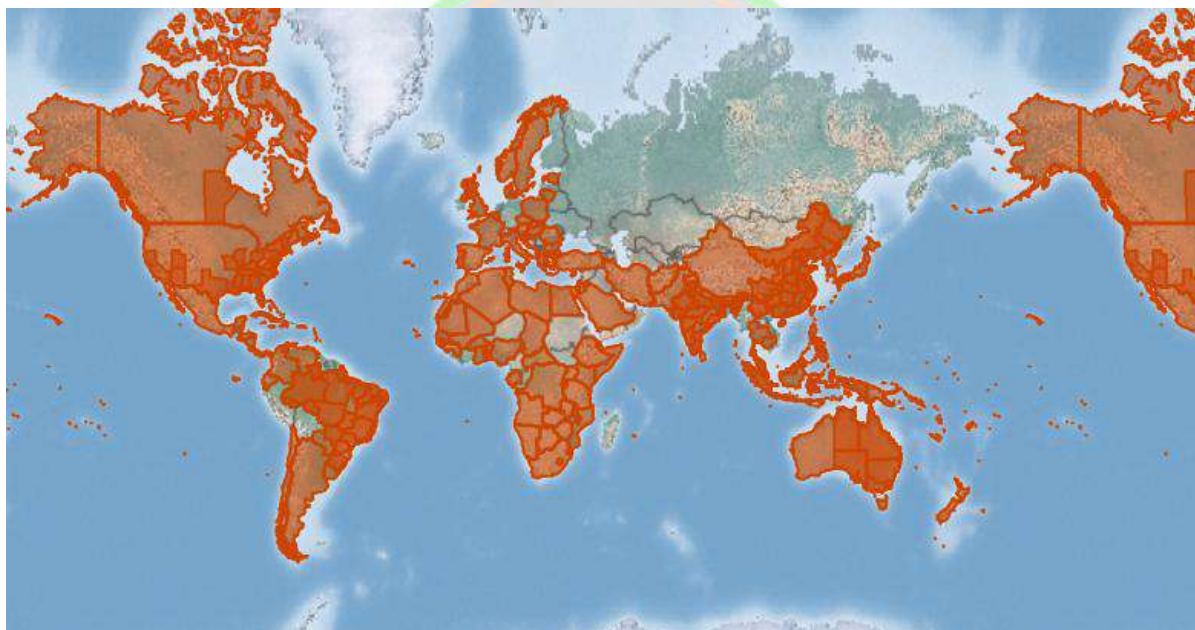


Fig. 1. World distribution of castor

De Candolle (1860) also has a similar view. But Fluckiger and Hanbury (fide Watt 1892) affirm that it is native to India. They hold this view mainly on the basis of knowledge of the medicinal uses of this plant as found in Sanskrit literature. Bentley and Trimen (fide Watt 1892) also believe that castor bean is native to India. Watt (1892) in his extensive tour of India found some evidence only at the foot of the Himalayas to show that castor bean is native of India. He, therefore, believed that it might have originated in India as well as in Africa. Hindus have known

castor oil from very ancient times. This oil has been mentioned in Susruta Ayurveda, one of the oldest works on Ayurveda. It is, therefore, possible that castor bean had originated in India or Africa. Castor bean is also believed to have polyphyletic origin with four centers of diversity, viz, (i) Ethiopian-East African, (ii) North–West and South–West Asia and Arabian Peninsula, (iii) Subcontinent of India, and (iv) China. However, Ethiopian-East African region is considered to be the most probable site of origin (Moshkin 1986). *Ricinus communis* is found in most drier areas of the tropics and subtropics and in many temperate areas with a hot summer.

It also naturally occurs across the African continent, from the Atlantic coast to the Red sea, from Tunisia to South Africa and in the Indian Ocean. It was introduced to Florida during the 18th century and was naturalized in Hawaii not later than 1819. It is becoming an abundant weed in Florida, California and Hawaii. The main producers of castor oil are India, Brazil, and China, which accounted for 93% of the world production in 2008. In 2019, India was by far the first producer of castor with 2 million t, followed by Brazil (31,000 t) and China (27,000 t) (Statista, 2020). The worldwide demand for castor oil increased by 50% from 1985 (400,000 t) to 2010 (610,000 t). It reached 813,200 t in 2018 and was expected to grow yearly by 4.1% between 2019 and 2025. In ancient Vedic texts, the castor oil plant, known as *Eraṇḍa* in Sanskrit, was used for various medicinal and practical purposes. It's mentioned in Ayurveda for its potential to treat wounds and its use in the Visodhana process, which involves cleansing impurities. The plant was also used to create bridges and as an analogy for the importance of humility.

HISTORY OF INTRODUCTION AND SPREAD:

Ricinus communis naturalizes easily and is found in the drier areas of many tropical and subtropical countries. It was cultivated for its oil in Egypt as long as 6000 years ago and from here, it spread through the Mediterranean, the Middle East, Asia, the Far East and India at an early date. Deacon (1986) summarizes the evidence for the very early introduction of this species into South Africa, with a number of archaeological records dating as far back as the Stone Age. In the USA, this species was first documented in Florida in the 1760s (Langeland et al., 2008) and, by 1819, it is listed as naturalized in Hawaii (Motooka et al., 2003). In the Caribbean, *R. communis* was first recorded in 1822 in Martinique and in 1883, in the US Virgin Islands (St Thomas; US National Herbarium). Buurt (1999) noted that it was introduced to Curaçao and Bermuda from the Old World, but he did not provide dates of introduction for those islands.

BOTANICAL DESCRIPTION:

Habitat: Grown in warm climate, sensitive to frost, heavy rain and water logging.

Habit: The plant is an annual herb or a perennial shrub, 1–7 m high, glabrous. In the wild, it reaches the size of a small tree. The plant height is highly influenced by the environment.

Roots: Tap root with prominent laterals producing a surface mat of feeding roots. The plant has well-developed tap root with prominent laterals which produce a surface mat of feeding roots (Purseglove 1968). The tap root looks like an extension of the stem below the soil. It can reach up to 5 m underground in extremely poor soil. The secondary roots are restricted to the upper 75 cm of the soil.

Stem: Erect, cylindrical branched, solid becoming hollow with age; green or reddish with well-marked nodes and prominent leaf scars. At first the single stem terminates into an inflorescence and as the panicle develops, sympodial branches grow out, one from each node immediately below it and these end in inflorescence and on or more sympodial branches grow out from the nodes immediately below them and the process is continued. The colour of the stem is variable. White (1918) classified the stem colour into five categories, viz, (i) bright green, (ii) green with reddish-bluish on the sunny side, (iii) carmine or rose-red, (iv) mahogany red, and (v) purple (dark red). Seshadri and Varisai (1951) reported four distinct stem colours, viz, mahogany, red, red-bluish and green.

Leaves: Alternate, simple, petiolate, palmately lobed, partite for about half length, serrate; multicostate, reticulate venation; spirally arranged Phyllotaxy, stipulate, petiole pale green or reddish brown deciduous; two nectariferous glands at junction to lamina; two glands on either side at base and one more glands on upper surface towards base.

Inflorescence: Terminal panicked cyme; unisexual male flowers at the base; female flowers on the top; some commercial hybrids entirely female. The blooms (waxy coating) are found on the stem and certain other parts of the castor bean plant. The colour of the bloom is ashy white. The types of bloom found on castor bean are described under the following categories: i. No bloom-with no bloom on any part of the plant, ii. Single bloom- with bloom only on the stem and not on leaves or fruit; iii. Double bloom – with bloom only on the stem, fruit and lower surface of the leaves and not on the upper surface of leaves and iv. Triple bloom- with bloom on the stem, fruit and lower and upper surface of the leaves. Usually, the main shoot and the branches terminate in inflorescences. The inflorescence is erect, 10–40 cm long, and terminal panicle of cymes

(panicked cymes). Under adverse soil and rainfall conditions, inflorescences often emerge when plants are hardly 20–30 cm tall, while the same cultivar under optimum soil and weather conditions gives out main panicle at a height of 180–220 cm. The panicle first appears in the form of a bud. The time required for the appearance of such bud from seeding varies with different cultivars. For the bud to develop into a panicle it takes 8–15 d. The flowers are usually unisexual and monoecious. The male (staminate) and female (pistillate)



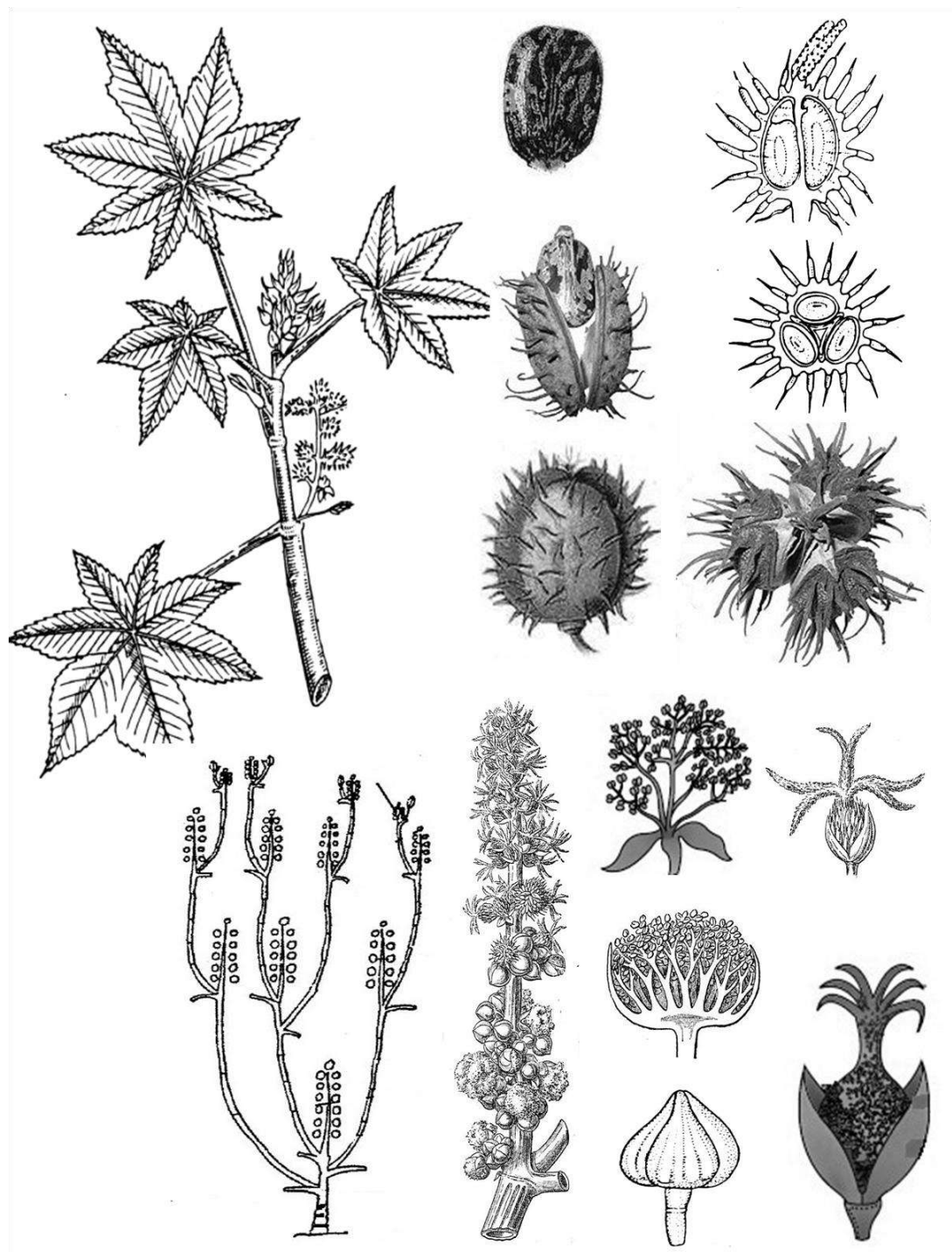
flowers are borne on the same inflorescence. The staminate flowers are at the base in 3–16 flowered cymes and the pistillate ones, on the top in 1–7 flowered cymes, occupying about 50–70 and 30–50%, respectively. In normal monoecious cultivars, the percentage of pistillate flowers along the rachis is usually the highest on the first panicle, with a decreasing percentage on subsequently developed panicles.

Male flowers: Pedicellate, ebracteate; calyx five or four, membranous, polypetalous, glaucous, green, or reddish, with waxy deposits (blooms), solid (pithy) becoming hollow with age, with well-marked nodes and prominent leaf scars, internodes shortest at base of the stem. A single stem is first produced which terminates in inflorescence at 6–10th node in dwarf early cultivars, at 8–16th node in later-maturing cultivars, and at 40th or more node in tall and wild plants. As the panicle develops, 2–3 sympodial branches grow out, one from each node immediately below it; they end in inflorescences and one or more sympodial branches grow out from the nodes immediately below them and the process continues. petalous, green valvate; corolla absent; androecium with five stamens profusely branched, and each branch ending in small spherical pale-yellow anthers; anthers basifixed.

Female flowers: Actinomorphic, incomplete, hypogynous, pedicellate; calyx three to five, membranous, caducus, spathaceous, valvate; corolla absent, gynoecium tricarpeal, syncarpous, covered with spiny outgrowth; single large ovule in each locule in axile placentation; style deeply bifid, flesh red papillate, long and persistent.

Fruit: Schizocarpic capsule or regma, splitting into three distinct portions each with its separate wall, persistent spiny out growth on fruit.

Seed: Ovoid, compressed dorsally, tick like, shining; pale grey or pale buff to almost black with dark mottling; yellowish white caruncle at base; testa brittle, endosperm copious, white, embryo small; cotyledons thin and papery.



SEX EXPRESSION IN CASTOR

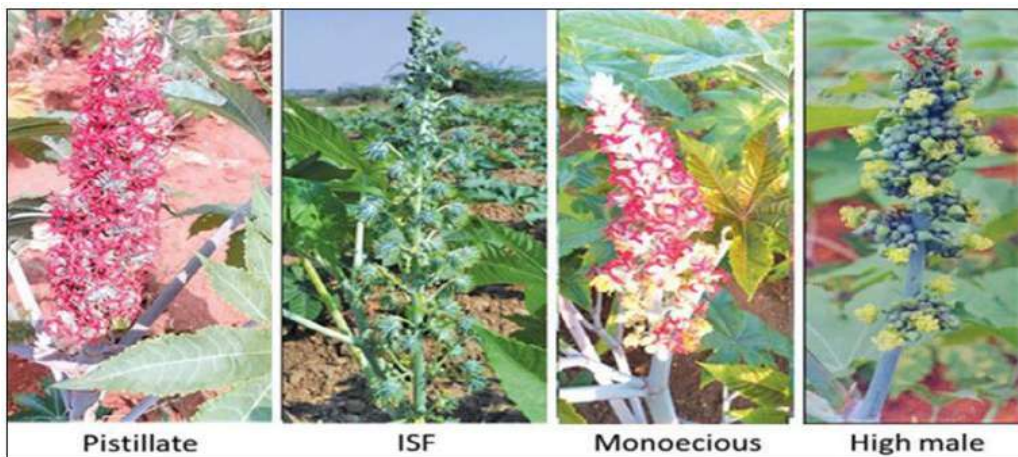
This intra-plant variation is generally associated with the seasons. Female tendency is the highest in spring and early summer; male tendency is the highest in mid- and late summer. Temperature is probably the main environmental component affecting sex. Moderate temperature promotes female flowers while high temperature promotes male flowers. However, age of plant and nutrition may also influence sex expression. Femaleness is the strongest in young plants with a high level of nutrition while maleness is the strongest in old plants with a low level of nutrition (Shifriss 1956 fide Milani and Nobrega 2013). In addition to monoecy, a subtype of dioecy occurs in plants with only pistillate flowers along the entire rachis of all panicles (Zimmerman and Smith 1966 fide Milani and Nobrega 2013). The counterpart, plants with only staminate flowers, occurs in **extreme climatic** conditions, with high temperature or water deficit.

Basic Sex Form in Castor includes

1. **Monoecious (M)**: It is the most natural occurrence of annual and perennial castor. The spike has basal 1/3rd to 1/2 male flowers while the top portion has female flowers. In between these few whorls have both male and female flowers in an interspersed fashion.
2. **Pistillate (P)**: It occurred as a rare recessive mutant with the spike having female flowers throughout the spike. It may be 100 per cent pistillate or < 100 per cent (70-90%) having a few male flowers in the basal portion.

Interspersed staminate flower (ISF): This is a modification of the pistillate with male flowers interspersed between the female flowers on the stem.

3. **Sex revertants**: In later stages, females become monoecious.



RELATED SPECIES OF CASTOR

Ricinus is a monotypic genus, but its sub species are in polymorphic forms viz.,

1. *Ricinus communis* subsp. *africanus*
2. *Ricinus communis* subsp. *chinensis*
3. *Ricinus communis* subsp. *gibsoni*
4. *Ricinus communis* subsp. *maxicanus*
5. *Ricinus communis* subsp. *pericus*
6. *Ricinus communis* subsp. *sanguineus*
7. *Ricinus communis* subsp. *zanzibarinus*

FLORAL BIOLOGY

The main shoot terminates in an inflorescence which is the oldest and those on the branches are later ones. It is generally believed that the male flowers open first and the female ones 1–2 d later. However, it has also been found that in many cases both male and female flowers open at the same time, and in a few cases either males or females open first. The male flower, after opening, sheds viable pollen grains for 1–2 d. The best weather conditions for pollen shedding are 26–29 °C temperature and 60% relative humidity (RH), which may vary according to cultivar. High temperature, plant age, and short-day length favor the appearance of male flowers. Dehiscence of anthers takes place between 4 a.m. and 8 p.m.. Pollen shedding occurs 2–3 h after sunrise until late afternoon with peak shedding at mid-morning. Pollen grains are viable for a long period ranging from 2 to 21 d with a viability of 76–26%, respectively. Regarding the female flowers, most researchers claim that the male flowers mature first and anthesis usually occurs in a short period of time before opening of the female flowers.

The stigma becomes fully receptive in a few hours after opening of the flower. It remains receptive for a period of 5–10 d after anthesis depending on environmental conditions. However, some researchers claim a short protogyny (Milani and Nobrega 2013). According to Hegde and Lavanya (2015), the stigma remains viable for 5–6 d and by tenth day, fertilization decreases to 9–10%. The exertion of the stigmatic lobes of the female flowers occurs at all hours, and it takes nearly 1–3 d for the stigmas to attain full development and become receptive from the time of opening of the female flowers. Stigmas remain receptive for 2–3 d. The flowers of the central panicle tend to self-pollinate (30–70%), and those of lateral panicles are cross-pollinated (Hegde and Lavanya 2015). A fairly high percentage of self-pollination occurs due to the structure of the

flowers and their disposition. But cross-pollination also takes place (Sundararaj and Thulasidas 1976). So, castor bean has a mixed mating system generating both self and cross-fertilized offsprings.

ECONOMIC IMPORTANCE

1. **Castor as oil seed crop:** Castor is an important oilseed crop with great utilitarian value in industry, pharmaceutical and agricultural sectors. The seeds contain between 40% and 60% oil. Its oil is unique among vegetable oils because the oil is the only commercial source of a hydroxylated fatty acid. The presence of hydroxyl groups and double bonds in the ricinoleic acid imparts unique chemical and physical properties on castor oil that makes the oil a vital industrial raw material. In the last couple of years, demand for castor oil has kept increasing in the international market, assured by more than 700 uses, ranging from medicine and cosmetics to biodiesel, plastics and lubricants.
2. **Castor Oil in Medicine and Cosmetics:** Castor oil is very effective laxative, and it is used as moisturizer for the treatment of skin problems like sunburn, wrinkles and fine lines, dry skin and stretch marks. It has also been claimed that it prevents infections like warts, boils, athlete's foot, acne, ringworm, and chronic itching.
3. **Castor Bean Meal and Husk for Animal Feed:** Detoxified castor bean meal (castor cake, pomace, oilcake), the residue left after extraction of oil, can be used as animal feed. Castor bean meal detoxified by boiling be added up to 100 g/kg in broiler finishing diets without any harmful effects. Castor bean meal detoxified by autoclaving can replace up to 67% of the soybean meal in sheep rations.
4. **Castor Bean Meal as an Organic Fertilizer:** The use of castor bean meal as organic fertilizer is very advantageous because of high N content, fast mineralization, and anti-nematode property. The mineralization of castor bean meal was found to be seven times faster than bovine manure and 15 times faster than bagasse of sugarcane.
5. **Castor Oil in Biodiesel:** Production of biodiesel from castor oil is technically feasible. The major constraint has been the high price paid for the oil as industrial oil because of high demand by the chemical industries to manufacture very high-value products.
6. **Castor in Ornamental Horticulture:** Castor bean is used extensively as a decorative plant in parks and other public places, particularly as a "dot plant" in traditional bedding schemes. If sown early, under glass, and kept at a temperature of around 20 °C until

planted out, the castor bean plant can reach a height of 2–3 m in a year. In areas prone to frost, it is usually shorter, and grown as if it were an annual.

- ‘Carmencita Bright Red’ – has red stems and bright red seed pods, along with dark purplish or bronzy-red leaves. This well-branched cultivar grows about 5-6 feet tall.
- ‘Carmencita Pink’ – has pinkish-red stems and seed pods.
- ‘Carmencita Rose’ – has blue-green foliage and peach-coloured seed pods.
- ‘Gibsonii’ – with dark red-tinged leaves and pinkish seed pods, it grows 4-5 feet tall.
- ‘New Zealand purple’ – has smaller, reddish purple leaves and branches less than other types.

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CLIMATE CHANGE AND LOW CARBON AGRICULTURE IN INDIA

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Introduction

Climate change presents a significant risk to global food systems and economic stability, with agriculture being both a major contributor to and victim of the crisis. In India, agriculture is a key sector that supports a large portion of the population and GDP, but it also accounts for a significant share of greenhouse gas (GHG) emissions. The country's intensive agricultural model, focused on high inputs and high outputs, has driven food production increases but also led to rising emissions of non-CO₂ gases like methane (CH₄) and nitrous oxide (N₂O). Livestock, particularly through enteric fermentation, is the primary source of methane emissions in India's agricultural sector, making emissions reduction from this sector a critical challenge.

India's agricultural emissions largely stem from rice cultivation, enteric fermentation, manure management, crop residue burning, and land-use change. Rice cultivation is a major source of methane due to the anaerobic conditions in flooded paddy fields, while livestock and manure management contribute significantly to both methane and nitrous oxide emissions. Additionally, the burning of crop residues, especially in northern India, is a widespread practice that not only adds to air pollution but also releases significant amounts of carbon dioxide and particulate matter. Deforestation and land degradation further exacerbate emissions, underscoring the need for sustainable practices that align agricultural production with environmental goals.

Aligning India's agriculture sector with the objectives of Sustainable Development Goal 13 (Climate Action) requires a transformative shift towards low-carbon, climate-resilient farming systems. A key strategy in this transformation is the adoption of Climate-Smart Agriculture

(CSA), which focuses on increasing productivity while reducing emissions and enhancing resilience to climate impacts. Practices such as efficient water management, crop diversification, and soil health improvement can help reduce the sector's carbon footprint. Additionally, sustainable livestock management practices, like improving feed efficiency and manure handling, can significantly reduce methane emissions from enteric fermentation and waste management.

To achieve this transformation, India must also focus on reducing methane from rice cultivation through techniques like Alternate Wetting and Drying (AWD), which reduces the time fields are flooded, and invest in alternative crop residue management practices to eliminate the need for burning. Government policies, technological innovations, and financial incentives for farmers to adopt low-carbon practices will be essential. Furthermore, promoting agroforestry and reforestation can sequester carbon, improve biodiversity, and mitigate land-use change emissions. A holistic approach that combines mitigation strategies with climate adaptation measures is necessary to ensure that agriculture can continue to support the economy while contributing to the global fight against climate change.

GLOBAL SCENARIO

In 2024, global greenhouse gas (GHG) emissions are projected to reach 58.9 gigatons (GT) of CO₂ equivalent, with cumulative emissions since 1850 estimated at 3,233.1 GT. The global average per-person emission stands at 7.4 tons, while emissions occur at a staggering rate of 1,867.5 tons per second. The Energy Systems sector is the largest contributor, releasing 21.5 GT, followed by Industry (14.4 GT), Agriculture (11.8 GT), Transport (8.1 GT), and Buildings (3.2 GT). These figures underscore the continued dominance of fossil fuel-driven energy and industrial processes in the global emissions landscape.

Focusing on agriculture, the sector contributes 11.8 GT of GHG emissions in 2024, translating to 1.5 tons per person and 372.4 tons per second. Within this, Land Use Change is the largest sub-sector, accounting for 5.2 GT (165.5 tons/sec), primarily due to deforestation and land degradation. Livestock emissions, largely from enteric fermentation and manure management, total 3.7 GT (117.2 tons/sec), while crops contribute 2.8 GT (89.7 tons/sec), driven by methane from rice fields, fertilizer use, and residue burning. These figures highlight the significant climate footprint of the global food system and the critical need for more sustainable agricultural and land-use practices worldwide.

INDIAN SCENARIO

As of 2024, India's total greenhouse gas (GHG) emissions stand at approximately 3.13 gigatons (GT) of CO₂ equivalent, excluding land use, land-use change, and forestry (LULUCF). The Energy Systems sector remains the dominant emitter, contributing around 75.8% of total emissions, followed by Industry (13.4%). Agriculture accounts for **roughly** 10–14% of total emissions, while the remaining share comes from transport and buildings. Although India continues to have lower per capita emissions compared to developed nations, the absolute levels remain high due to the country's population and economic activity.

Within the agriculture sector, livestock (especially enteric fermentation) **is** the largest source of emissions, responsible for about 54.6% of the sector's total, followed by fertilizer application (19.1%), rice cultivation (17.5%), **manure** management (6.7%), and field burning of crop residues (2.2%). These trends highlight the urgent need for climate-smart agricultural interventions. With India striving for a net-zero target, transforming agriculture through sustainable practices, emissions-efficient livestock management, and better residue handling will be critical in reducing the sector's carbon footprint while maintaining food and income security.

The global and Indian greenhouse gas (GHG) emissions scenarios reveal both shared challenges and differences. In 2024, global emissions are projected at 58.9 GT of CO₂ equivalent, with agriculture contributing 11.8 GT, primarily due to land use change (5.2 GT), livestock emissions (3.7 GT), and crop-related **activities** (2.8 GT). India's emissions, at approximately 3.13 GT, are much lower in total, though agriculture still contributes 10-14% of the country's emissions, with livestock (enteric fermentation) being the largest source, followed by fertilizer use, rice cultivation, and manure management. The global agricultural sector's dominant sources are land use change, livestock, and crop practices, with deforestation being a major issue globally. In India, livestock emissions account for over half of agricultural emissions, and crop residue burning is a significant concern, especially in northern states. Both scenarios highlight the need for sustainable practices, such as improved livestock management, efficient fertilizer use, and reduced deforestation, to mitigate emissions. While India's per capita emissions remain lower than those of developed nations, the absolute emissions are high due to its large population. Both global and Indian efforts to achieve net-zero targets hinge on transforming agricultural practices to reduce emissions, with climate-smart agriculture playing a central role in mitigating the sector's carbon footprint.

FUTURE EMISSION

The emissions forecast for 2030 and 2035 highlights the ongoing challenge of managing agricultural greenhouse gas (GHG) emissions. By 2030, total emissions are projected to reach 807 Mt, showing an increase from 746 Mt in 2025. The rise in emissions across agricultural sources is driven by several factors, including continued growth in rice cultivation, which contributes to methane emissions, and an expanding livestock sector, leading to higher enteric fermentation emissions. Crop residue burning and manure management also remain significant sources of emissions, with projected increases in these areas as agricultural practices continue to rely on high-input, high-output methods.

For 2035, total emissions are forecasted to rise further to 837 Mt, indicating a steady upward trend in emissions over the next decade. Rice emissions are expected to increase to 134,251 kt as the demand for food production grows, and enteric fermentation emissions will reach 431,826 kt due to a larger livestock population. Manure management will also contribute to higher emissions, with 41,024 kt projected by 2035. The continued practice of crop residue burning is expected to rise to 27,253 kt, and forest fire emissions will increase slightly to 5,081 kt. This data highlights the ongoing need for targeted climate action to mitigate agricultural emissions.

The forecasted rise in emissions calls for urgent interventions in agricultural practices. Key strategies include promoting Climate-Smart Agriculture (CSA) techniques such as alternate wetting and drying (AWD) in rice fields to reduce methane emissions. Additionally, improving livestock management through better feeding practices, waste treatment technologies, and methane capture can help curb emissions from enteric fermentation and manure. Shifting away from crop residue burning to sustainable disposal methods such as composting or using residues for bioenergy will be essential in reducing emissions and their associated environmental impacts.

POLICY SUGGESTIONS

To mitigate the increasing greenhouse gas (GHG) emissions from agriculture, a comprehensive policy approach is essential. Promoting low-carbon farming practices is one of the key strategies. The adoption of practices like Alternate Wetting and Drying (AWD) and System of Rice Intensification (SRI) can significantly reduce methane emissions from rice cultivation by improving water management and reducing the need for constant flooding of rice paddies. In addition, promoting bio-digesters and composting as part of manure management will

help minimize nitrous oxide emissions by processing manure efficiently. Moreover, encouraging precision agriculture which uses drones and satellite mapping will optimize the use of fertilizers and water, thereby minimizing input waste and reducing emissions. These practices, when implemented at scale, could significantly reduce the sector's carbon footprint while improving farm productivity.

Reforming agricultural subsidies is another important policy recommendation. Subsidies should be linked to emission-reducing technologies, such as low-emission fertilizers and mechanized residue management tools. This would provide financial incentives for farmers to adopt sustainable practices that reduce emissions. Moreover, penalties for residue burning, which is a major contributor to air pollution and GHG emissions, should be enforced. By making subsidies conditional on adopting climate-smart practices, the government can encourage farmers to shift towards more sustainable and environmentally friendly methods of farming. These reforms would not only lower emissions but also ensure that financial support is used to drive long-term sustainability.

The introduction of carbon labelling and trade standards could also play a significant role in reducing emissions. By introducing carbon labelling for agricultural products, especially in export markets, consumers would be better informed about the carbon footprint of the products they purchase, creating a demand for low-carbon goods. Furthermore, carbon border adjustments could be implemented to account for the embedded emissions in traded goods, ensuring that imports and exports reflect their true environmental impact. This would level the playing field for domestic producers adopting low-carbon practices and incentivize the global supply chain to prioritize sustainability.

In addition to these practices, developing the AFOLU (Agriculture, Forestry, and Other Land Use) sector as a key source of carbon sinks is crucial. Promoting agroforestry, soil carbon sequestration, and organic farming can contribute to long-term carbon storage, helping mitigate emissions while enhancing biodiversity and farm resilience. Funding for these activities could be facilitated through carbon credit mechanisms and international climate finance, encouraging farmers to engage in activities that sequester carbon. Furthermore, strengthening data and forecasting systems is essential for effective policymaking. A centralized agricultural emissions monitoring platform using remote sensing and artificial intelligence (AI) can provide real-time data, allowing for the tracking of emissions and informing future policy decisions. Regularly



updating GHG inventories will help refine strategies and ensure the continued alignment of policies with climate goals.

Finally, capacity building and farmer awareness are critical to the success of any climate-smart agriculture initiative. Launching training programs at the grassroots level to educate farmers on low-carbon practices and climate resilience will empower them to adopt sustainable farming techniques. Additionally, developing village-level carbon farming models will allow farmers to see firsthand the economic benefits of reducing emissions and improving soil health. By building a strong knowledge base and fostering a sense of ownership, farmers can become active participants in climate change mitigation, ensuring the success of these policies at the community level.



COCONUT WONDERS: A NATURAL MULTI-USE MARVEL

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Introduction

Coconut tree is a member of the palm tree family and the only living species of the genus cocos.

- Scientific name: ***Cocos nucifera***
- Family: **Arecaceae**

India produced 14,682,000 metric tons in 2023, ranking third globally behind Indonesia and Philippines. India's coconut production has been growing at a compound annual growth rate (CAGR) of 5.8% since 2014. The major coconut-producing states in India are Kerala, Tamil Nadu, Andhra Pradesh and West Bengal.

In 2019, the total area under coconut cultivation in India was approximately 20,535.88 hectares. India's coconut productivity has increased over the years, with Kerala showing a significant rise in productivity. Karnataka produced 4,329.83 million coconuts in 2020-21, accounting for around 29% of India's total coconut production. The Average annual coconut production is around 4,000 million nuts. Karnataka has approximately 4,2lakh hectares under coconut cultivation, with an average productivity of 10,500 nuts per hectare.



Dakshina Kannada, the highest-producing district, has a productivity of 12,300 nuts per hectare.

Farmers in this region have mastered the art of coconut farming, using traditional and modern techniques to ensure a steady supply of coconuts throughout the year.

Every Part of the Coconut Tree Has Its Own Innovation

COIR:

Coir is a natural fibre extracted from the husk of coconut.

Coir is a Tamil word “Kayir”. Seeing back the history ropes were made using this husk or the fibre. Coir are used as organic matter for agricultural and horticulture crops. These fibres are also used as bed for the cultivation of mushrooms.

Coir Production Process

The coconut husk is soaked in water to loosen the fibre. Then, it is beaten to separate the fibres, which are then cleaned and dried in the sun. The fibres are sorted according to their length. This process is called “retting.”

Major Uses of Coir

Coir is used to make eco-friendly bricks and tiles, which are lightweight and biodegradable. It is used to create biodegradable products such as pots or mulch. Coir is used in making mats and rugs, which are durable and resistant to dirt.

Coir fibers are woven into twine and ropes, which are strong and resistant to saltwater. Coir is used in textile products such as jackets, leather boat cushions, and pants made from coir fibers.

Coir can be used as scrubbers or brushes for various household activities. Coir is used as packaging material in industries, offering a biodegradable alternative to plastic.

It helps prevent soil erosion by being used in erosion control applications.

COCONUT LEAF:

Coconut leaves are versatile and popular for decoration.



Thoranam: A traditional decoration made by interlocking coconut leaves, commonly used for weddings and festivals.

Coconut Leaf Garland: Dried or fresh coconut leaves are strung together to create garlands for weddings or everyday decor.

Pandal Decoration: Leaves are used to decorate temporary structures for festivals or weddings, and to create shelters in rural areas.

Wall Hangings: Coconut leaves are arranged into patterns and hung on walls or in gardens as decorative pieces.

Brooms: Dried coconut leaves are used to make eco-friendly brooms that are effective and low-cost.

Baskets & Hats: Coconut leaves are woven into baskets, mats, and hats as creative handicrafts.

COCONUT TIMBERS (WOOD)

Coconut wood is used for various decorative and practical purposes:

Carving: Coconut wood is carved into intricate decorative items such as boxes, chests, and containers.

Wall Art: It is used to create wall panels and decorative screens.

Kitchen Utensils: Coconut wood is used to make spoons, forks, chopping boards, and bowls.

Furniture: Coconut wood is used to make chairs, tables, photo frame outlines, and dining tables.

Wood Carvings: Carvings are made using knives, chisels, and hand tools to create sculptures, such as animals, birds, and human figures.

Coconut Shell

The coconut shell is a hard outer layer that protects the coconut flesh.



Coconut shells are used to make various handicrafts, including bowls, vases, teapots, ice-cream cups, pen stands, lampshades, pots, and ladles.

They are also used to produce charcoal, which is commonly used for ironing, cooking, and other household purposes. Coconut charcoal is stronger than other types of charcoal.

Coconut shells are durable and biodegradable.

Coconut (Kobbari)

Kobbari, or dry coconut, is used in various cultural practices:

Wedding Decorations: Kobbari is used to create wedding arches, mandaps, and other elements, adding a natural and traditional charm to events like engagements, marriages, and baby showers.

Conclusion

The use of natural, eco-friendly coconut fibers helps reduce reliance on non-biodegradable plastic products.

Coir plays a crucial role in reducing chemical use in agriculture.

Coconut-based products are affordable and provide additional income opportunities for farmers. ★ ★ ★ ★

Processing coconut husk into coir does not require glue, making the process more sustainable.

Coconut shells are versatile and can be used in numerous ways.

These products have endless possibilities, contributing to sustainability and environmental conservation. By promoting coconut-based products, we are encouraging eco-friendly practices and reducing waste.



IMPACT OF CLIMATE CHANGE ON SOIL AND WATER RESOURCES

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Introduction

Climate change is no longer a distant threat; it is an immediate reality reshaping ecosystems, economies, and communities across the globe. Among its many impacts, the consequences for soil and water resources are some of the most profound yet often underappreciated. These two natural resources are the foundation of food security, biodiversity, and environmental sustainability. As the climate shifts, understanding the intricate ways it affects soil and water is crucial for developing adaptation and mitigation strategies.

The Nexus Between Climate and Natural Resources

Soil and water are intricately linked. Healthy soils regulate water cycles, support plant growth, and act as carbon sinks. Water resources—rivers, lakes, aquifers—depend on precipitation, runoff, and infiltration, all of which are influenced by soil health and climate patterns. When the climate changes, this balance is disrupted.

1. Impact on Soil Resources

a. Soil Erosion

One of the most visible impacts of climate change on soil is increased erosion. Intense rainfall events, driven by global warming, lead to more surface runoff, which washes away the topsoil—the most fertile layer. Once lost, it takes hundreds of years for nature to regenerate this layer.

Regions with sloped terrains or loose soils are particularly vulnerable. For example, in tropical and subtropical zones, heavy downpours combined with deforestation and poor land practices have accelerated soil erosion, reducing agricultural productivity.

b. Soil Organic Matter and Carbon Sequestration

Soils are the largest terrestrial carbon reservoir. Climate change, particularly rising temperatures and altered precipitation patterns, can accelerate the decomposition of organic matter in soils. As microbes break down organic material faster, more carbon dioxide is released into the atmosphere, creating a feedback loop that exacerbates climate change.

Moreover, droughts and water stress limit vegetation growth, reducing organic inputs to the soil. This further depletes soil organic carbon, undermining soil fertility and the ability of soils to retain water and nutrients.

c. Salinization

As temperatures rise and rainfall becomes erratic, salinization—the buildup of salts in the soil—becomes more pronounced. This is especially true in irrigated lands, where poor drainage and high evaporation rates concentrate salts near the surface. Saline soils inhibit plant growth and microbial activity, diminishing agricultural yields and soil health.

d. Soil Structure and Compaction

Climate change also affects the physical properties of soil. Wet-dry cycles, increasing due to erratic weather patterns, disrupt soil aggregates and pore spaces. During dry periods, soils can become hard and compacted, reducing infiltration and root penetration. Heavy rains on these compacted soils can lead to crusting and further erosion.

e. Soil Biodiversity Loss

Soil is teeming with life—from bacteria and fungi to insects and earthworms. This biodiversity is crucial for nutrient cycling, soil structure, and plant health. However, increased temperatures and changing moisture regimes can alter microbial communities and stress soil organisms, leading to a decline in soil biodiversity. This reduces the resilience of soils to disturbances and lowers their productivity.

2. Impact on Water Resources

a. Changes in Precipitation Patterns

Climate change is altering rainfall patterns globally. Some regions experience more intense and frequent storms, while others suffer from prolonged droughts. These shifts have

major implications for water availability. In arid and semi-arid regions, declining rainfall is already stressing freshwater supplies, while increased rainfall in other areas can lead to flooding and water contamination.

b. Droughts and Water Scarcity

Prolonged periods of drought, now more common in many parts of the world, severely reduce river flows, groundwater recharge, and reservoir levels. Agricultural irrigation, drinking water supplies, and hydropower generation all suffer during extended dry spells. Crops wilt, livestock suffer, and communities face increased competition over shrinking water resources.

Droughts also affect groundwater. As surface water becomes scarce, more communities rely on groundwater extraction, which, if unmanaged, leads to over-extraction, falling water tables, and aquifer depletion.

c. Glacial Melt and Water Security

In regions dependent on glacial meltwater—such as the Himalayas, Andes, or the Alps warming temperatures are causing glaciers to retreat rapidly. While this initially increases river flows, it is unsustainable in the long run. Eventually, as glaciers shrink, meltwater will decrease, threatening the water supply of hundreds of millions of people.

d. Water Quality Degradation

Rising temperatures, increased stormwater runoff, and drought can all impact water quality. For instance:

- **Higher temperatures** promote algal blooms in lakes and reservoirs, which can produce toxins harmful to humans and aquatic life.
- **Runoff from heavy rains** often carries pesticides, fertilizers, and sediments into water bodies, leading to eutrophication and contamination.
- **Droughts** reduce the dilution capacity of rivers, concentrating pollutants and increasing salinity in freshwater systems.

e. Sea Level Rise and Saltwater Intrusion

Coastal aquifers and estuaries are vulnerable to sea level rise. As sea levels rise, saltwater can intrude into freshwater aquifers and surface water bodies. This not only reduces freshwater availability but also affects soil health through secondary salinization, especially in deltaic regions like the Sundarbans or the Mekong Delta.

3. Implications for Agriculture and Food Security

The twin stress on soil and water resources directly undermines agriculture. Crop yields depend on fertile soil and adequate water. With soils losing their fertility, organic matter, and structure, and with water becoming increasingly scarce or erratic, farmers struggle to maintain productivity.

Smallholder farmers in developing nations are particularly at risk, as they lack the resources to invest in irrigation, improved seeds, or soil conservation technologies. As climate change continues, the gap between food demand and supply could widen, increasing hunger and economic instability.

4. Socioeconomic and Environmental Consequences

The degradation of soil and water resources **does not only** impact agriculture. It also affects:

- **Livelihoods:** Many rural communities depend on farming, fishing, or forest products—all of which are sensitive to changes in natural resources.
- **Biodiversity:** As habitats degrade, flora and fauna suffer. Wetlands dry up, forests thin out, and aquatic ecosystems collapse.
- **Migration and Conflict:** Water scarcity and land degradation can push people to migrate in search of better living conditions. In some cases, competition over dwindling resources leads to conflict and social unrest.

5. Mitigation and Adaptation Strategies

Despite the grim outlook, various strategies can help mitigate the impact of climate change on soil and water resources.

a. Sustainable Soil Management

- **Conservation agriculture:** Practices like minimal tillage, cover cropping, and crop rotation help maintain soil structure and organic matter.
- **Agroforestry:** Integrating trees into farms improves soil fertility, prevents erosion, and supports water retention.
- **Organic amendments:** Adding compost or biochar enhances soil health and carbon sequestration.

b. Water-Smart Practices

- **Efficient irrigation:** Techniques like drip or sprinkler irrigation reduce water use and minimize salinization.

- **Rainwater harvesting:** Collecting and storing rainwater can supplement irrigation and recharge groundwater.
- **Watershed management:** Protecting and restoring watersheds enhances infiltration and water availability downstream.

c. Climate-Resilient Infrastructure

Building climate-resilient infrastructure such as flood control systems, reservoirs, and early warning systems helps buffer against extreme weather events.

d. Policy and Community Engagement

- **Integrated resource management:** Policies should consider the interconnection between soil, water, agriculture, and climate.
- **Capacity building:** Educating farmers and local communities about sustainable practices empowers them to adapt.
- **Incentives and subsidies:** Supporting conservation efforts through financial incentives encourages wider adoption of good practices.

6. Role of Technology and Innovation

Modern technology can support adaptation and resilience:

- **Remote sensing and GIS** tools allow monitoring of soil moisture, vegetation health, and land use changes.
- **Decision support systems** help farmers plan water use and crop choices based on real-time weather data.
- **Biotechnology** offers drought-resistant crops that thrive in water-limited and degraded soils.

Conclusion

The impact of climate change on soil and water resources is one of the most critical challenges of our time. These resources are foundational to life, and their degradation threatens food security, economic stability, and ecosystem integrity. However, with the right mix of science, policy, innovation, and community engagement, we can build resilient systems that sustain both people and the planet. Protecting soil and water isn't just an environmental issue—it's a survival imperative. As climate change accelerates, so must our actions to safeguard these vital resources for future generations.

IMPROVEMENT OF KARONDA (*Carissa carandas*) THROUGH BREEDING TECHNIQUES

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Abstract

Karonda (*Carissa carandas*), a resilient and underutilized fruit crop of high nutritional and medicinal value, offers significant potential for crop improvement through breeding. This technical bulletin reviews both conventional and modern breeding techniques employed to enhance Karonda traits such as fruit size, yield, and stress tolerance. Important approaches include selection, hybridization, mutation breeding, and emerging methods like marker-assisted selection and genome editing. Challenges such as self-incompatibility and limited genomic resources are discussed, along with future prospects for research and commercialization. Integrating traditional knowledge with advanced technologies can unlock the full potential of Karonda in sustainable horticulture.

Keywords: *Carissa carandas*, Karonda breeding, conventional breeding, hybridization, mutation breeding, marker-assisted selection, molecular breeding, germplasm evaluation, underutilized fruit crops, stress tolerance.

Introduction

Karonda, a hardy, spiny, evergreen shrub or small tree, belongs to the family Apocynaceae. It is indigenous to India and is widely found in the subcontinent, including the Himalayan foothills, peninsular India, and parts of Southeast Asia. The fruit is known for its high nutritional value, especially vitamin C and iron, and is traditionally used in pickles, jams, jellies, and chutneys. Medicinal uses also include treatments for anemia, diarrhea, and skin infections.

Despite its potential, Karonda remains largely underutilized due to lack of improved high-yielding varieties, poor postharvest management, minimal research and breeding efforts, and genetic variability. Improving Karonda through advanced breeding techniques can enhance its commercial viability, yield, and quality traits, contributing to both nutritional security and rural livelihoods.

Botanical and Genetic Background

Species: *Carissa carandas*

Family: Apocynaceae

Chromosome number: $2n = 22$

Morphology: Spiny shrub with milky latex; leaves are simple, opposite, and dark green. Flowers are white and fragrant, while fruits vary in color from green to deep purple or black when ripe.



Figure 1. Karonda plant with fruits

Karonda exhibits considerable natural genetic variability in traits like fruit size, color, shape, and taste; thorn density; plant architecture; and maturity period. This diversity forms the basis for selection and breeding programs. Germplasm conservation and evaluation play a vital role in utilizing this variability for trait improvement.

Breeding Objectives

Improvement of Karonda aims at the following traits as shown in table 1.

Breeding Techniques Used in Karonda Improvement

Breeding techniques used for the improvement of Karonda can be categorized into conventional and modern approaches. Each method plays a vital role in addressing specific challenges related to yield, quality, stress tolerance, and consumer preferences.

Conventional Breeding Techniques

Selection

This is the most widely adopted and successful method in Karonda improvement. It involves identifying and selecting superior genotypes from naturally occurring populations or landraces based on phenotypic traits such as fruit size, color, yield, taste, and thorniness. For instance, genotypes with bold fruits and reduced thorniness have been selected from wild populations in Gujarat and Maharashtra. Clonal selection ensures the perpetuation of desired traits through vegetative propagation.

Hybridization

Although hybridization is less frequently employed due to floral biology and self-incompatibility issues, it holds promise for generating new recombinants. Controlled crossing between elite parents is performed to combine desirable traits, such as high vitamin C content and early maturity. However, success depends on overcoming barriers like low fruit set and managing the long juvenile phase.

Table 1. Trait wise objective of Karonda

Sl. No.	Trait	Objective
1	Fruit Quality	Increased size, uniform shape, higher vitamin C, reduced astringency
2	Yield	High and consistent productivity, shorter juvenile phase
3	Abiotic Stress Tolerance	Resistance to drought, salinity, temperature, extremes stress
4	Biotic Stress Resistance	Resistance to pests and diseases
5	Plant Architecture	Dwarf types, fewer thorns for ease of harvesting
6	Improved Rootstocks	Stress-tolerant and compatible for grafting

Mutation Breeding

Mutation breeding has been explored to induce variability in otherwise genetically uniform populations. Physical (e.g., gamma rays) and chemical mutagens (e.g., EMS) are used to develop mutants with beneficial traits like compact growth, thornlessness, and better pigment content. This method requires extensive field trials for screening and evaluation of mutant lines.

Polyploidy Breeding

This involves inducing chromosome doubling using colchicine to develop polyploid plants, which often exhibit traits like larger fruit size and greater stress tolerance. Though still under research, this method shows potential in enhancing productivity and quality.

Modern Breeding and Biotechnological Approaches

Marker-Assisted Selection (MAS)

MAS facilitate the identification and introgression of target traits at the seedling stage using molecular markers. This technique speeds up breeding by enabling the selection of individuals carrying desired genes without waiting for maturity. For Karonda, it can be particularly useful in selecting traits like disease resistance and high antioxidant content.

Genomic Studies and Bioinformatics

Recent advances in sequencing technologies have allowed partial genome sequencing and transcriptome profiling in Carissa species. These studies reveal genes involved in fruit ripening, pigment synthesis, and stress responses, enabling gene-based breeding strategies.

In Vitro Propagation and Somaclonal Variation

Micropropagation is used to produce large numbers of genetically identical elite plants. Tissue culture also helps to preserve valuable germplasm and overcome propagation limitations. Sometimes, tissue-cultured plants show somaclonal variation, which can be a source of new traits.

Genetic Engineering and Genome Editing

Although not yet commercialized in Karonda, tools like CRISPR/Cas9 and transgenic technologies offer future potential for precise trait modification, such as improving nutritional quality or developing pest-resistant lines.

Speed Breeding

By manipulating environmental factors such as light, temperature, and photoperiod, generation time can be shortened, allowing more breeding cycles per year. This is particularly

useful for perennial crops like Karonda.

Germplasm Collection, Characterization, and Evaluation

Germplasm collection from diverse agro-climatic zones is crucial. Characterization is based on morphological and molecular markers such as RAPD and SSR.

Propagation Techniques

Conventional methods include seed propagation and vegetative methods such as grafting and layering. Modern methods like micropropagation enable rapid multiplication. Table 2 shows promising Varieties and Breeding Lines.

Table 2. Promising Varieties and Breeding Lines

Variety/Selection	Institution/Origin	Key Traits
CHES-K-1	Central Horticultural Experiment Station (CHES, Vejalpur	Large fruits, high yield
CHES-K-2	CHES, Vejalpur	Early maturing, drought tolerance
Pant Sudarshan	GBPUA&T, Pantnagar	High TSS, low acidity
Konkan Bold	DBSKKV, Dapoli	Bold fruits, suited for processing

Challenges in Breeding Karonda

Challenges include self-incompatibility, low fruit set, long juvenile phase, lack of genomic resources, and poor farmer awareness.

Future Prospects and Research Priorities

Future directions include genome sequencing, CRISPR/Cas9 gene editing, cisgenics, and climate-resilient breeding. Development of value chains and public-private partnerships is also crucial.

Conclusion

Improving Karonda through breeding offers significant potential for enhancing its nutritional, medicinal, and commercial value. Integrating traditional and modern techniques will be key to sustainable improvement and wider adoption.

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EXPORT STANDARDS FOR DOMESTIC AND INTERNATIONAL MARKET FOR VEGETABLES

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Introduction

India is the second largest producer of vegetables in world, but it shares in export of vegetables is only about 2% of total agricultural exports. India has a total area of 8.5 million ha under vegetables cultivation, producing 146.55 million metric tonnes of vegetables, with an average productivity of 173.Mt ha⁻¹ during 2010-2011. Compared to other agricultural commodities, the international commerce in fruits and vegetables has grown at a faster rate, particularly since the 1980s. The worldwide patterns and dynamics of this trade have not received much attention, despite the fact that fruits and vegetables currently account for a sizeable portion of global agricultural trade.

Grades of vegetables

Fruit grade indicates and assure internal and external quality to the buyer and fetches a good price for the producer. Sorting and grading in large operations are mechanized. Grade Standards/Quality Standards, There are various agencies that have established grade and quality standards including packaging regulations for fruits and vegetables. Codex Alimentarius Commission is the most significant on a global scale. In order to harmonize International Food Standards, create guidelines and codes of practice to safeguard consumer health, and guarantee fair procedures in the food trade. (WHO and FAO 1963).

Grade Designations

According to the Agmark grading standards for fruit quality, fruit is categorized into three grades or classes based on its quality. The following grade designation/classification is generally recommended for all fruits: i) Additional instruction ii) Class I iii) Class II Besides

Codex Alimentarius Commission and Agmark, various other bodies have also developed standards for quality of fruits, notably for exports to certain nations . (viz APEDA and NHB 2003).

Quality

The term quality implies the degree of excellence of a product or its suitability for a particular use. Quality of produce encompasses sensory properties (appearance, texture, taste and aroma), nutritive values, chemical constituents, mechanical properties, functional properties and defects.

Appearance is detected instrumentally by measuring electromagnetic (usually optical) properties, texture, by mechanical properties, and flavor (taste and aroma) by chemical properties.

Sorting

Sorting is required to provide the consistent quality needed for commercial purposes as well as to separate the undesired, acceptable, and exceptional individual pieces. High-speed, non-destructive sensors are needed for sorting in order to measure multiple characteristics of each fruit or vegetable.

Methods of Determining Quality

Legal standard

Mandatory standard established by federal state or Municipal agencies Set up by law or represented by appropriate a Concerned with freedom from adulteration and Proper quality control measures that is insects, molds, yeasts, pesticides, maximum limit of Preservative, and food without contamination.

Company or volunteer label standard

Established by food industry represents consumers image and becomes Trademark symbol of product quality are used by private firms or supermarkets.

Industry standard

Established by an organized group for any given Commodity Becomes effective by pressure from market Organization or specific commodity group where Legal standards are not involved .

Consumer or grade standard

Represents consumer's requirement of a grade/ Standard product Based on experience in

use by the industry for consumers.

Physical method

Size, texture, color, consistency, headspace, fill and drained Weight, vacuum, container, symmetry, defects, viscosity.

Chemical method

Enzyme, moisture, fiber, pH, acidity, protein, specific Gravity, fat/oil, carbohydrate, ash, mineral, vitamins and sugars.

The grade and standard of different vegetables crops are index

Beans

a) EU Standards

- i) Extra Class: tender, seedless and stringless, tolerance of 5 per cent by weight, 6 mm in size.
- ii) Class I: Slight discolouration, small seeds, short and soft strings, tolerance of 10 per cent by weight.
- iii) Class II: Beans which do not qualify for Class 1.

Brinjal

a) EU Standards

- i) Class I: Cracks covering not more than 3 sq cm, tolerance of 10 per cent by weight.
- ii) Cracks covering not more than 4 sq cm, tolerance of 10 per cent by weight
- iii) May be slightly fibrous and show considerable seed development, cracks covering Not more than 6 sq cm, tolerance of 15 per cent by weight.
- iv) The diameter 40 mm for elongated brinjal and 70 mm for global brinjal.

b) Indian standard

- i) Super
- ii) Fancy
- iii) Commercial.

Carrot

a) EU Standards

- i) Extra Class: green and purple tops are not allowed, tolerance of 5 per cent by weight
- ii) Class I: green or purple tops up to 1cm long, tolerance of 10 per cent by weight
- iii) Class II: green or purple tops up to 3cm long, tolerance of 10 per cent by weight, broken tops not more than 25 per cent

- iv) Early carrot roots must be 10-40mm in diameter and 8-150g in size
- v) For storage carrot roots must be 20-45mm in diameter and 50-200g in size.

Garlic

a) EU Standards

- i) Extra class: compact cloves, roots must be cut-off, tolerance of 5 per cent by weight, 45 mm in dia
- ii) Class 1: tolerance of 10 per cent by weight, not more than 1 perCent should have visible sprouts, 30 mm in dia)
- iii) Class II: tolerance of 10 per cent by weight, Not more than 5 per cent should have visible sprouts, 30 mm in dia.

b) Indian Standards

- i) Big: 30mm
- ii) Medium: 25mm
- iii) Small: 10mm
- iv) Mix: 10-12mm
- v) Tolerance of 5 per cent by weight

Onion

a) EU Standards

- i) Class I. blemishes should not cover 10 per cent
- ii) Class II: blemishes should Not cover 10 per cent
- iii) Class III: blemishes should not cover 20 per cent

b) Indian standard

- i) Extra big: min diameter: 60mm
- ii) Big :30-40 mm
- iii) medium : 20-30 mm
- iv) Small: 15-20mm
- v) Mix: 15-20mm
- vi) Not more than 2 per cent should be decayed, tolerance of 5 per cent by weight.

Pea

a) EU Standards

Class 1: well-filled containing at least 5 seeds, tolerance of 10 per cent by weight.

Class 2: 3 seed.

Potato

Potatoes generally grades onto four sizes,

A Grade: >100g (above 100g);

B grade: 50-100g;

C grade: 25 -50g and

D grade: <25g (below 25g).

Storage

The basic principle of storage is to reduce the rate of physiological processes like respiration, transpiration, ripening and other biochemical changes . Proper storage also aims at controlling disease infection and preserving the commodity in its best quality for consumers. (ISO 1991).

Important of storage

- a) Slow down hiological activity
- b) Reduce product drying and moisture loss
- c) Reduce pathogenic infection
- d) Avoid physiological disorders
- e) Reduce physical damage

Factor affecting storage

- i.Pre harvest factors
- ii.Maturity at harvest
- iii.Harvesting and handling practices
- iv. Pre-storage treatments
- V. Temperature and humidity in storage room.
- vi. Overall hygieneTemperature and relative humidity.

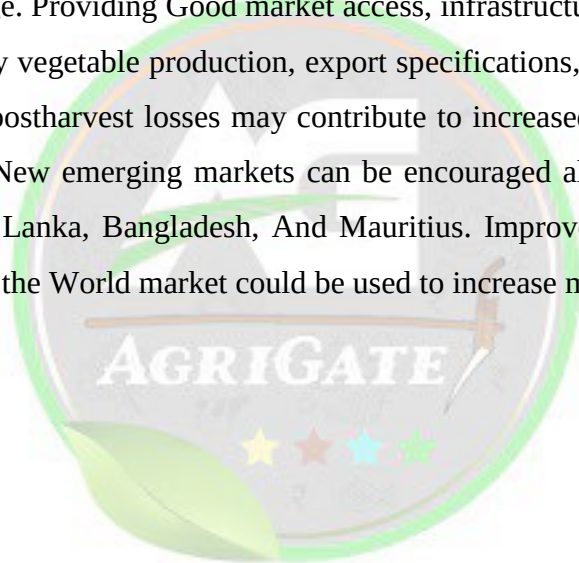
Export Competitiveness of Fresh Vegetables in India

Total vegetable exports from India were around US\$464 million in 2010–2011, including 2.12% of agricultural exports and 12.8% of horticultural exports. India is the second Largest producer of vegetables in the world and 24th in export of vegetables. Major destinations of India's fresh vegetable exports are the United Arab Emirates (UAE), Nepal, Sri Lanka, the United Kingdom, and Saudi Arabia, together accounting for 55% of total Vegetable exports from India.



Vegetable productivity in India is lower than the world average, 18.8 Mt·ha⁻¹. Potato (*Solanum tuberosum* L.), tomato (*S. lycopersicum* L.), and onion (*Allium Cepa* L.) are major vegetables grown in India, covering 44.6% of total area Under vegetable cultivation and 50.3% of total vegetable production, followed By eggplant (*S. melongena* L.), cabbage (*Brassica oleracea* L. var. capitata), Cauliflower (*B. oleracea* L. var. botrytis), and peas (*Pisum sativum* L.)

India has export potential in onion, potato, and tomatoes and a comparative advantage in exporting onion and to some extent peas. The major Destinations of vegetable exports are mainly Middle East countries. India has Been able to achieve export competitiveness and market share in very few Fresh vegetable crops due to heavy postharvest losses up to 25% of production, poor quality of the produce, and lack of adequate Infrastructural facilities for processing, transportation, and storage. Providing Good market access, infrastructural facilities, awareness to farmers regarding Quality vegetable production, export specifications, and improved postharvest Technologies to reduce postharvest losses may contribute to increased foreign Trade of Indian-grown vegetable crops. New emerging markets can be encouraged along with existing ones in Singapore, Pakistan, Sri Lanka, Bangladesh, And Mauritius. Improved quality of produce and better competitiveness in the World market could be used to increase market share.



MEDICINAL MUSHROOMS

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Introduction

Mushrooms are a group of fleshy saprophytic fungi that are found growing on dead organic matter. Over 10,000 species of mushrooms are believed to be found naturally growing in moist, damp forests and soils rich in organic matter throughout the world. Among these, some are edible while others are toxic. A few species of mushrooms are known for their medicinal properties as well and hence they are known as medicinal mushrooms. This article presents a comprehensive review of various medicinal mushrooms.



Milky Mushrooms (*Calocybe indica*)

Milky Mushrooms (*Calocybe indica*): These are milky-white delicate mushrooms which are one of the most delicious and nutritious mushrooms. Milky mushrooms are tropical in growth habit and are very popular in India and other Asian countries. It is found growing naturally in the damp, moist forest environments of Indian subcontinent. Favorable temperature range for its growth is considered to be 25-30o C.



Paddy Straw Mushrooms (*Volvariella volvacea*)

Paddy Straw Mushrooms (*Volvariella volvacea*): Paddy Straw mushrooms are subtropical in growth habit and are successfully grown in areas with high rainfall. Favorable temperature range for its growth is considered to be 30 – 35°C. They are very popular in India, China, Taiwan, Thailand and other South East Asian countries. Substrate material popularly used for its cultivation is paddy straw and therefore the name ‘paddy straw mushrooms’.



White Button Mushrooms (*Agaricus bisporus*)

White Button Mushrooms (*Agaricus bisporus*) : These are one of the most widely consumed mushrooms in the world. They are believed to be cultivated in more than 100 countries. These mushrooms are popularly known as button mushrooms, white mushrooms, and table mushrooms. Good compost and good quality spawns and a simulated environment are absolute necessities for its successful growing. Favorable temperature range for its growth is 15°C to 17°C.



Brown Mushroom

Brown Mushroom: Brown strain of *Agaricus bisporus* is known as brown mushrooms. There are two types of brown mushrooms. Baby Crimini mushrooms and mature portabella mushrooms. Crimini mushrooms have a darker or brown color, deeper flavor and denser texture than the white button mushrooms.



Crimini Mushrooms

Crimini Mushrooms: Crimini mushrooms are also known as Swiss brown mushroom, Roman brown mushroom, Italian brown mushrooms and Italian mushrooms. They are believed to be originated in Europe and North America.



Portabella Mushrooms

Portabella Mushrooms: Portabella mushrooms are mature Crimini mushrooms, which are three to seven days older than the Crimini. Because of their extended growing period, portabellas have larger caps and deeper color. Ideal temperature for the growth of both the Crimini and the portabellas are considered to be 24oC and 15-17oC.



Shiitake Mushrooms (*Lentinula edodes*)

Shiitake Mushrooms: Scientific name of Shiitake Mushrooms is *Lentinula edodes*. Shiitake Mushrooms are fleshy, brown-colored mushrooms that are known for their medicinal properties. Ideal temperature for the growth of shiitake mushrooms is considered to be 18-24°C. Shiitake mushrooms are believed to be originated in East Asia. These mushrooms are known for both their edible as well as medicinal properties. Shiitake mushrooms are considered to be a good remedy for premature ageing and respiratory problems.



Oyster Mushrooms (*Pleurotus spp*)

Oyster Mushrooms: Scientific name of Oyster mushrooms is *Pleurotus spp*. Oyster mushrooms can be grown on many substrates, and are very easy to cultivate even for a beginner; it takes hardly one or two months to complete one cycle of production, starting from spawning to harvesting to marketing. Ideal temperature for the growth of oyster mushrooms is considered to be 20-30°C. There is a large type of oyster mushroom called 'King Oyster Mushroom'. King oyster mushrooms are very popular in India and surrounding regions and are known by the name 'Kabul dhangri'. Ideal temperature for the growth of king oyster mushrooms is considered to be 17-20°C.



Enoki Mushrooms(*Flammulina velutipes*)

Enoki Mushrooms: Scientific name of Enoki Mushrooms is *Flammulina velutipes*. Enoki mushrooms or Enokitake (Enokidake) are white colored, thin long mushrooms that are popular South East Asian countries such as China, Japan and Korea. They are also known as golden needle mushrooms and lily mushrooms.



Maitake Mushrooms (*Grifola frondosa*)

Maitake Mushrooms: Scientific name of Maitake Mushrooms is *Grifola frondosa*. Maitake mushrooms are believed to be originated in Japan and North America and they are still very popular in Japan. In Japanese language, the word ‘Maitake’ means “dancing mushroom”, a name given due to its growing characteristics; they are perennial fungi and often grow in the same place in succession and occur in clusters at the base of the trees. Common names of Maitake mushrooms are Hen-of-the-Woods, Ram’s Head and Sheep’s Head. Maitake mushrooms are believed to control blood sugar and cholesterol. It has anti-cancer and anti-obesity properties. Regular consumption of Maitake mushrooms strengthens body’s immune system.



Morel Mushrooms (*Morchella esculenta*)

Morel Mushrooms: Morel Mushrooms (*Morchella esculenta*) are one of the most delicious mushroom varieties in the world and are highly popular in France. They are used extensively in

many types of French cuisines. They are commonly known by their popular name ‘sponge mushrooms’. They are very popular in Germany and USA also.



Chanterelle Mushrooms (*Cantharellus cibarius*)

Chanterelle Mushrooms: Chanterelle Mushrooms (*Cantharellus cibarius*) are a group of golden-colored, fleshy, funnel-shaped edible fungi known for their excellent edible properties. They are very popular in Europe, North America, Africa and Asia. They are found naturally occurring in moist, temperate coniferous forests. Chanterelle mushrooms are normally consumed after cooking and they are suitable for drying also. Dried chanterelle mushrooms are powdered and used for seasoning soups and sauces



NUCLEAR MAGNETIC RESONANCE (NMR) - INTRODUCTION TO PLANT PATHOLOGY

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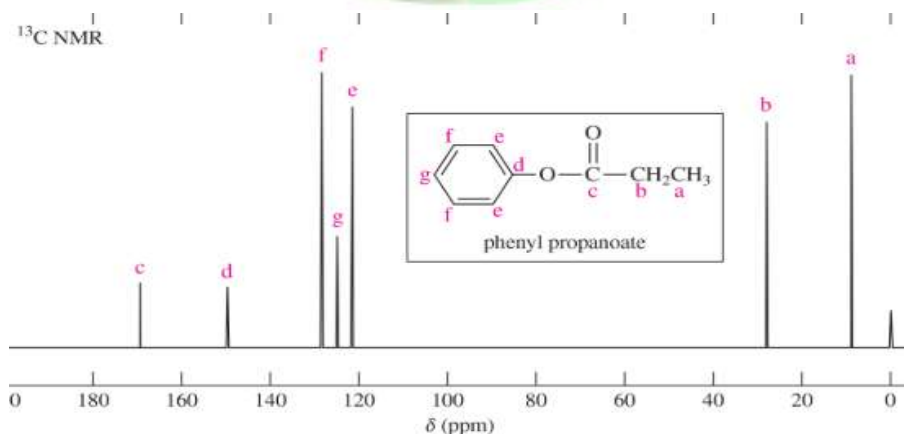
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Introduction

Nuclear magnetic resonance (NMR) is a physical phenomenon in which nuclei in a strong constant magnetic field are perturbed by a weak oscillating magnetic field (in the near field) and respond by producing an electromagnetic signal with a frequency characteristic of the magnetic field at the nucleus. This process occurs near resonance, when the oscillation frequency matches the intrinsic frequency of the nuclei, which depends on the strength of the static magnetic field, the chemical environment, and the magnetic properties of the isotope involved; in practical applications with static magnetic fields up to ca. 20 tesla, the frequency is similar to VHF and UHF television broadcasts (60–1000 MHz).

Fig1.C13 NMR spectroscopy



NMR results from specific magnetic properties of certain atomic nuclei. Nuclear magnetic resonance spectroscopy is widely used to determine the structure of organic molecules in

solution and study molecular physics and crystals as well as non-crystalline materials. NMR is also routinely used in advanced medical imaging techniques, such as in magnetic resonance imaging (MRI).

Fig2. N NMR spectroscopy

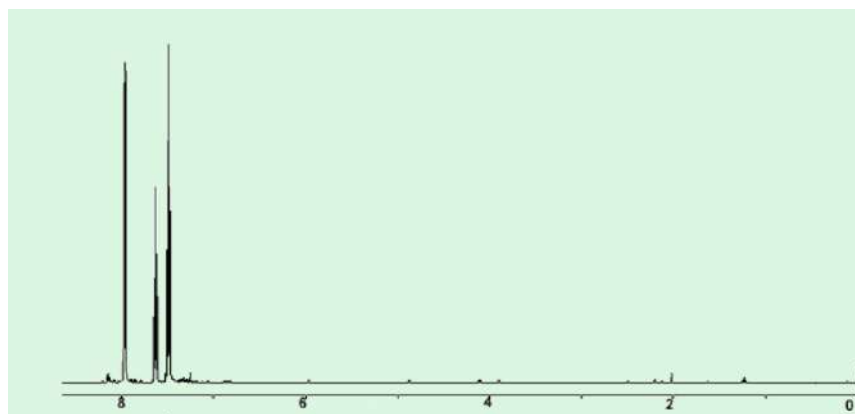


Fig3. Difference between proton and carbon-13 NMR spectroscopy

S.NO.	¹³ C-NMR	PMR
1	Study of spin changes of carbon nuclei.	Study of spin changes of proton nuclei.
2	Chemical shift ranges between 0-240 ppm.	Chemical shift ranges 0-14 ppm
3	Very fast process	Very low process
4	Pulse-Fourier transform technique is used	Continuous wave method is used.
5	Value of coupling constant ranges from 125-250 HZ	Ranges from 0-15 HZ
6	Information of total number of protons carbons is obtained.	Information like total number, types of chemical environment of protons is obtained.
7	By peak splitting, possible to interpret protons directly attached to carbon atom	It possible to interpret protons attached to adjacent carbon atom
8	Effect of substitute on substitute on adjacent carbon atom cannot vary the chemical shift.	Substituent alters the chemical shift.
9	It works on frequency sweep	It works on either field sweep or frequency sweep.

	¹ H NMR	¹³ C NMR
Relative size of signals	¹ H atoms area of signals for ¹ H atoms Determines number of H+	¹³ C atoms <u>No link</u> between area of signal to number of ¹³ C atoms
Splitting of signals	Signal split by ¹ H atoms on adjacent atom(s)	<u>No splitting.</u> <u>No Integration calculations</u>

NMR Equipment

NMR magnets: Even though an ultrahigh magnetic field NMR spectrometer, such as one set at 950 MHz, will offer better resolution and higher sensitivity, such equipment is prohibitively expensive and the maintenance is similarly costly. Consequently, most NMR-based metabolomics studies have been conducted using 600 and 500 MHz NMR spectrometers that are commonly available in research institutes and offer a good compromise between resolution, sensitivity, and cost. 2. NMR probes: Different NMR probes can be used for particular applications and for the detection of different nuclei. Examples of commercial NMR probes that have commonly been used in metabolomics research include:

(a) Double Resonance Broad Band Probes (BBO and BBOF) often called Broad Band Inverse Probes. These are widely used in experiments such as heteronuclear 2D experiments involving single-quantum coherence (HSQC), heteronuclear multiple-quantum correlation (HMQC), and heteronuclear multiple bond correlation (HMBC).

(b) Triple Resonance Broad Band Probe (TBI). TBI can be used for all BBO applications, the extra channel bringing the advantage of being able to study another X-nucleus, so providing the capability for study of organometallic compounds and metalloproteins using ^1H , ^{13}C , and another metal-nucleus.

(c) Double Resonance Broadband Probe (BBI). Tunable to a wide range of frequencies; used for detection of multinuclear experiments optimized for ^1H applications.

(d) Triple Resonance Broad Band Probe (TBO). TBO probe has features similar to those of BBI probe but with one extra channel. (e) Triple Resonance Probe (TXI). Provides the opportunity to pulse for up to three or four nuclei in one experiment; used extensively for NMR structural determination of biological macromolecule

Methodology:

NMR spectroscopy is a powerful analytical tool that has been used mainly in chemistry for the identification and quantification of the chemical composition of a given sample. The applications of NMR spectroscopy are not limited to liquid samples but can also be used on solid, gas phase, and tissue samples. Moreover, as well as its main applications in molecular identification and structural elucidation, NMR can also be used to study the physical and chemical properties of molecules, such as electron density and molecular dynamics. Consequently, NMR has become the main tool for structural biology studies as it enables

researchers to study molecular structures as well as molecular dynamics under biological conditions. Moreover, NMR spectroscopy has been employed in a wide range of research areas including structural biology, organic chemistry, inorganic chemistry, biochemistry, physics, biology, polymers, and drug discover. NMR spectroscopy has been proposed as one of the most relevant methods in metabolomics applications, for example, as powerful diagnostic method for a wide range of human diseases.

Low sensitivity is the inherent disadvantage and the foremost challenge for the application of NMR in biomedical research. Continuous developments in the relevant machinery such as a higher magnetic field strength, cryogenically cooled probes, and microprobes have significantly enhanced the sensitivity of NMR. The dynamic nuclear polarization (DNP) approach is one of the most efficient developments that has been used successfully to enhance NMR sensitivity in imaging and spectroscopy

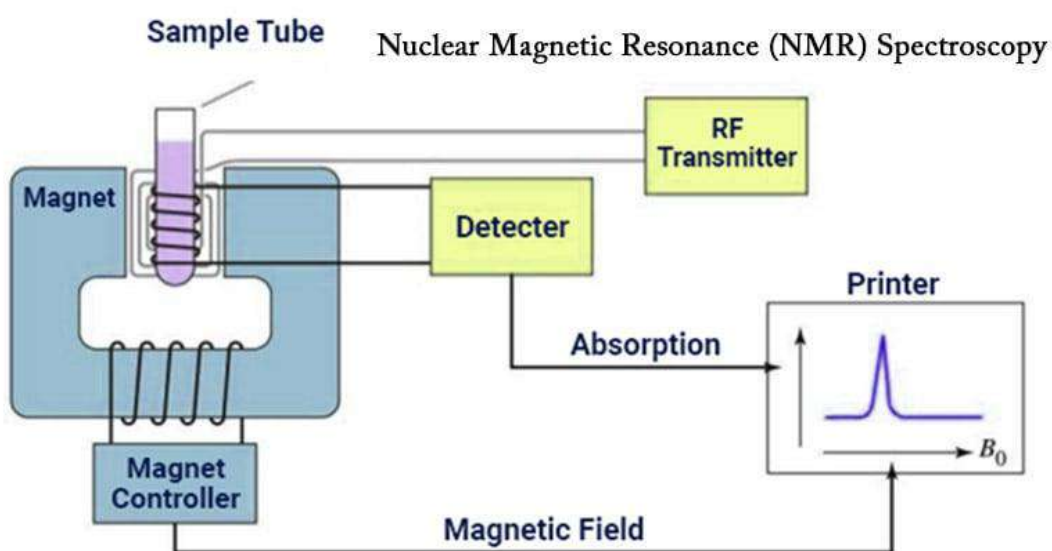


Fig. 2.Overall methodology for Nuclear Magnetic Resonance (NMR) Spectroscopy

Principle of Nuclear Magnetic Resonance (NMR) Spectroscopy

1. The principle behind NMR is that many nuclei have spin and all nuclei are electrically charged. If an external magnetic field is applied, an energy transfer is possible between the base energy to a higher energy level (generally a single energy gap).
2. The energy transfer takes place at a wavelength that corresponds to radio frequencies and when the spin returns to its base level, energy is emitted at the same frequency.

3. The signal that matches this transfer is measured in many ways and processed in order to yield an NMR spectrum for the nucleus concerned.

Instrumentation of Nuclear Magnetic Resonance (NMR) Spectroscopy

1. **Sample holder**

Glass tube with 8.5 cm long, 0.3 cm in diameter.

2. **Permanent magnet**

It provides a homogeneous magnetic field at 60-100 MHz

3. **Magnetic coils**

These coils induce a magnetic field when current flows through them

4. **Sweep generator**

To produce an equal amount of magnetic field pass through the sample

5. **Radio frequency transmitter**

A radio transmitter coil transmitter that produces a short powerful pulse of radio waves

6. **Radio frequency receiver**

A radio receiver coil that detects radio frequencies emitted as nuclei relax to a lower energy level

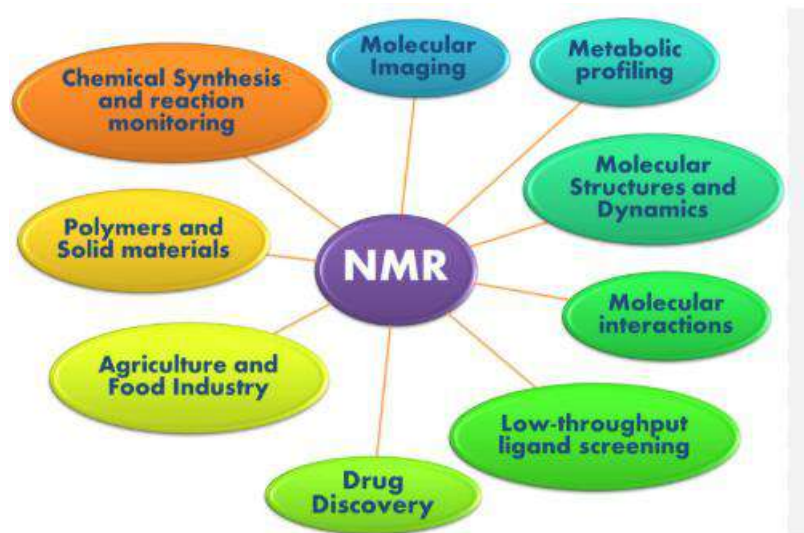
7. **Read out systems**

A computer that analyses and records the data.

Working of Nuclear Magnetic Resonance (NMR) Spectroscopy

- The sample is placed in a magnetic field and the NMR signal is produced by excitation of the nuclei sample with radio waves into nuclear magnetic resonance, which is detected with sensitive radio receivers.
- The intramolecular magnetic field around an atom in a molecule changes the resonance frequency, thus giving access to details of the electronic structure of a molecule and its individual functional groups.
- As the fields are unique or highly characteristic to individual compounds, NMR spectroscopy is the definitive method to identify monomolecular organic compounds.
- Besides identification, NMR spectroscopy provides detailed information about the structure, dynamics, reaction state, and chemical environment of molecules.
- The most common types of NMR are proton and carbon-13 NMR spectroscopy, but it is applicable to any kind of sample that contains nuclei possessing spin.

Application of NMR



Nuclear Magnetic Resonance (NMR) spectroscopy

Nuclear Magnetic Resonance (NMR) spectroscopy is an analytical technique used to determine the chemical molecular structure of a compound. NMR Testing provides both quantitative and qualitative data on the composition of a sample.

Conclusion

It can provide extensive information about the structure, dynamics, and chemical environment of atoms. Additionally, NMR spectroscopy is ideally suited to distinguish different functional groups or identical functional groups in different molecular environments.

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PAN-GENOMICS

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Introduction

Understanding genetic diversity within a species is required for various population, evolutionary and conservation genetic studies, and this knowledge is essential to understand species' phenotypic variation, as well as mechanisms allowing environmental adaptation (Hirsch *et al.* 2014; Carlos Guimaraes *et al.* 2015). However, estimation of genetic diversity is based on the data, methods, and technologies available at the time of analysis. Thus, while Carl Von Linné or Georges-Louis de Buffon classified animals and plants based on visual phenotypic observations, nowadays biologists deal with large molecular dataset, and diversity estimations are based on genetics and genomics approaches and dataset.

Most genomic investigations in plants emphasized on the single nucleotide polymorphisms (SNPs) due to their relative ease of identifications in different populations but with increasing knowledge of genome sequencing, the concept of single reference genome now seems insufficient. Most recent approach in this regard is pan-genome (originated from Greek term pan, which means whole) which came into existence with the development of an initial pan-genome, for a bacterial species *Streptococcus agalactiae*. Total number of genes for a species are collectively classified as its pan-genome where its construction and annotation is a prerequisite for recognizing variations within different species. Essentially, the concept of pan-genome is based on the fact that a single reference genome cannot represent all strains within the species

due to various sequence variation causing mechanisms such as copy number variations (CNVs), presence/absence variations (PAVs), and SNPs.

Increasing number of evidences recommend that a sole organism does not have capability to contain all the genetic information of a species due to different variations in the genomic sequences. Thus, the assembly of the pan-genome is necessary to determine the extent of genomic variation. And by comparing individual gene and sequence contents within a population, pangenomics is a great tool to investigate how sequences evolve within a species and how genetic diversity is shaped within it.

WHAT IS A PAN-GENOME?

Pan-genome is the non-redundant set of genes or genomic sequences within a species. The prefix “pan” came from the Greek $\pi\alpha\nu$, meaning “all”, while genome denote the complete set of nuclear and cytoplasmic genes present in an organism.

Pan-genome studies are performed on a set of organisms/individuals supposed to be representative of a family, a genus, or more generally a species. These analyses provide a large array of phylogenomic information at different levels, from general implications for the group to individual-specific genetic information. Pangenomics is also a way to characterize how conserved are the genomic sequences between individuals within a population. As a corollary, two individuals may not be similar to each other because of the genes they share, but a N N NN also for the ones they missed.

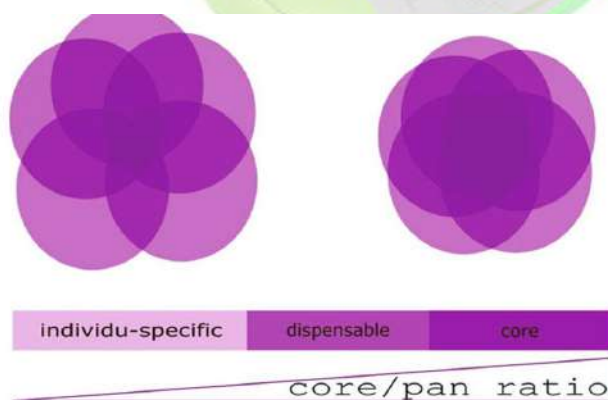


Figure 1. Pangenome with high or low core/pan ratio. Each individual is represented by a different circle. Intersection between all circles represents the core genome, parts without intersection represent the individual-specific genome, and intersections with not all circle the dispensable genome

A core/pan ratio (i.e., size of core vs size of pangenome, in bp) greater than 90% indicates a high rate of genome conservation between sampled individuals. On the other hand, if this ratio is lower than 85%, then the species may present a certain potential of adaptability because of a higher genomic diversity. Indeed, in this case, if we consider the population, individuals are different enough from each other to be able to respond to rapid and/or abrupt changes and increase the chances of survival for the species as a whole.

MATHEMATICAL MODEL

First, the subsets of the pan-genome are identified by the use of orthology analyses, which first identify all orthologous genes from the complete dataset using all-vs-all blasts or other alignment search tools. Next, the datasets are classified according to their homology to genes from other strains in the subsets. After the classification, the data is plotted in a chart and mathematical formulas are used to fit the specific curves. Two such formulas are Heaps' law for the pan-genome development and least-squares fit of the exponential regression decay for the core genome and singleton subsets, which are described respectively as: $n = kN^{-\alpha}$, where n is the number of genes, N is the number of genomes, and k and α are constants defined by the formula; and $n = ke^{-x/\tau} + tg\theta$, where n is the number of genes, x is the number of genomes, e is Euler's number, and k , τ , and $tg\theta$ are constants defined by the formula.

TYPES OF PANGENOME

A pan-genome is classified as open or closed (limited). (Figure 2)

According to Heap's law, the α value is representative of the current dynamics of the pan genome, where an α higher than 1 is representative of a closed pan-genome and an α lower than 1 represents an open pan-genome.

1. Open pan-genome

Open pan-genome approach refers to the condition when there is no fixed quantity of the genes in a species and whenever a new organism is included in the pan-genome analysis, there is a probability of identification of the novel genes.

2. Closed pan-genome

Closed pan-genome approach the gene pool is restricted and the pan-genome analyzed based on the definite number of individuals (or samples, strains) would not be extended in terms of gene numbers with the genome of additional individuals analysed.

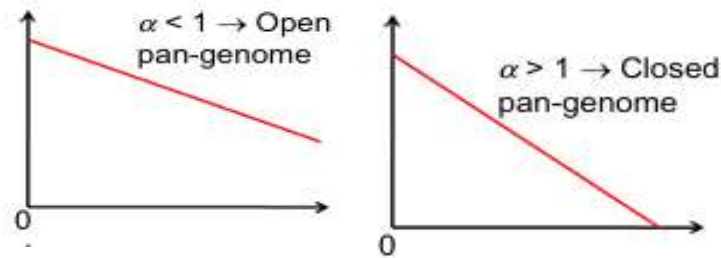


Figure 2. The concept of open and close pan-genome.

STRUCTURE AND DYNAMICS OF PANGENOME

The concept is based on the realization of the increasing structural variation evidences from sequencing data making a single genome reference insufficient to depict the entire diversity of the genome of species. The genomes even among different individuals are variable from each other to different extents in species. Thus, the pan genomes capture this diversity as a core genome and a variable genome (Figure 3). The variable genome is further categorized as either dispensable genome or species specific genome.

Core Genome: The core genome is made of genes/sequences present in all individuals of the studied group.

Dispensable Genome: Dispensable genes are found in at least two individuals among those studied, but not in all.

Species-Specific Genome: Genes belonging to a single individual are grouped which is a sub-part of the dispensable genome.

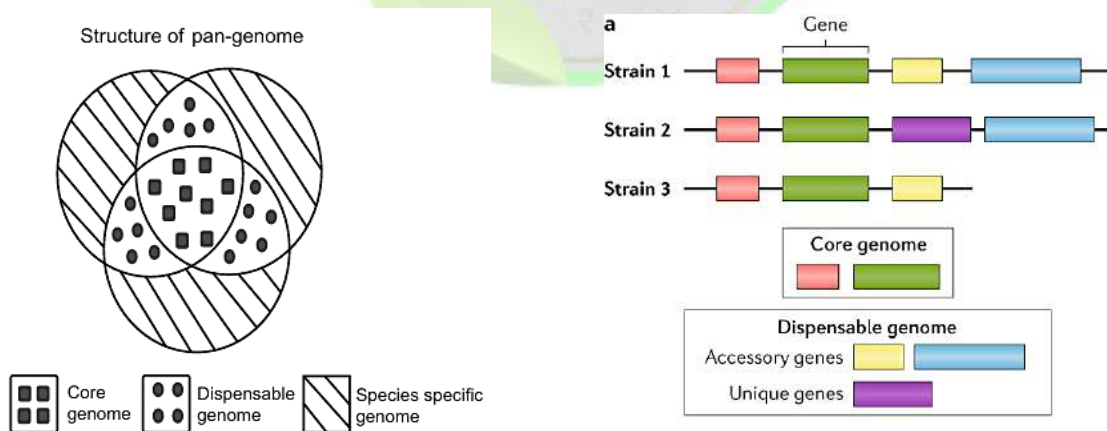


Figure 3. Structure of a pan-genome

The plant genomes are even more complex than many higher eukaryotic organisms mainly due to polyploidy and presence of repetitive genomic segments. Some of the plant genomes contain multiple copies of full chromosomes arising either from spontaneous duplication event

(autopolyploidy) or through hybridization from other species (allopolyploidy). The repetitive genomic segments in plants genomes can vary from 10% (as present in *Arabidopsis*) to 80% (as present in wheat bread). Overall, the main sources of structural variations (SVs) leading to diversity and complexity to plants genomes include SNPs, deletions, insertions, duplications, and genetic rearrangements. These genomic structural variations with respect to studies of plants genomes can be broadly categorized into two types that is, CNVs and PAVs. The CNVs correspond to the presence of multiple copies of a genetic segment/feature in an individual genome whereas PAVs correspond to the presence or absence of genomic segments or features in different individuals (Figure 4). Thus, the total genetic composition of plants genomes may highly vary among the individuals of same species which is dependent on the CNVs and PAVs.

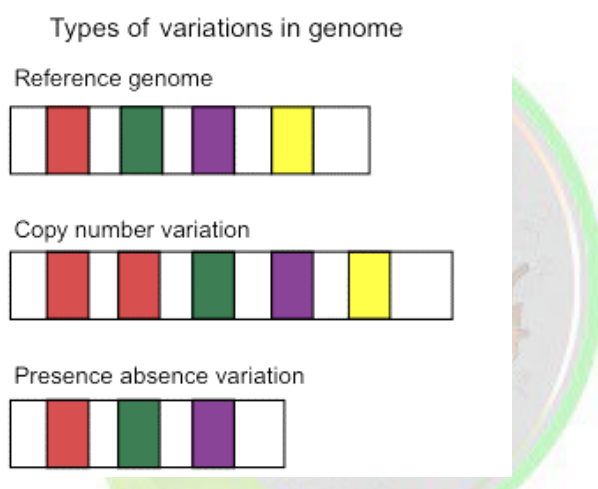


Figure 4. Two different types of variations in the pan-genomes, that is, copy number variations (CPVs) and presence-absence variations (PAVs) are illustrated.

The CNVs particularly can affect the phenotypes of plants depending on their own role (being regulatory regions or gene themselves) and location of integration in the genome. On the basis of these changes, CNVs may contribute to cause changes in genes expression, structure, and identification of recessive alleles. These structural variations can be both beneficial and deleterious and their identification can increase our understanding of their roles in better adaptation to the environment and the diseases susceptibility of plants.

PANGENOMICS METHODOLOGIES

Two types of methods dedicated to pangenomics studies can be distinguished. The first method is for building the pangenomes from the dataset, and the second method is for analyzing

the pangenome already built from the dataset, and to identify the core, dispensable, and individual-specific genome.

Methodologies to Build Pangenome

To date, different methods have been used for the assembly of plant pan-genomes broadly categorized into k-mer-based approach, comparative de-novo assembly approach, and iterative assembly approach.

1. k-mer-based approaches

The pan-genomes can be assembled using k-mer-based approaches in which the sequences are represented as a set of strings of length k (called k-mers). The sequences belonging to the whole genomes, contigs or sequencing reads are broken down into k-mers which can be then visualized using a special type of graph representation called as De Bruijn graphs. The nodes in this graph are the k-mers and the two k-mers are connected with each other based on the overlapping sequence relationship between them. k-mers are connected with an edge between them if they overlap by $k-1$ characters. Whole genomes can be assembled or reconstructed using this approach by taking into the account the information regarding nodes and their relationship to each other. Since, many reads/sequences can overlap with each other, the formed graph can be complex and many nodes can be connected to form loops like structures. However, for a pan-genomics analyses in which we have to take into the account different genomes, the color code is used to identify the origin of k-mer. The nodes (k-mers) specific to one particular sample are assigned unique colors whereas the k-mer common to all of the samples are assigned single color. This information is then used to construct the pan-genome in the form of a colored De Bruijn graph. The edges between these colored nodes in a colored De Bruijn graph allows easier trace back of each genome along with the identification of common and unique sequences in the pan-genome.

2. Comparative *de novo* assembly approach

A *de novo* assembly approach refers to the process of individual genome assembly without using a reference genome. The comparative de-novo gene assembly approach refers to the comparison of the *de-novo* assembled genomes of multiple samples/ strains/individuals constructed from de-novo assembly approach using whole-genome alignments. It allows for identification of variable and shared regions in the genomes along with orthologous gene clusters and core or variable gene families if followed by the annotations of genomes. This approach is

particularly useful for conducting a pan genome analysis as it allows largest identification of the SVs and CVS when compared to other approaches. However, comparative de novo assembly approach is a computationally extensive approach and high sequencing coverage of individuals is a prerequisite for it in Pan-genomics of plants 295 order to allow their individual assembly.

3. Iterative assembly approach

The iterative assembly approach is useful for low-coverage sequencing samples. A single whole-genome assembly is used as a reference genome and reads from all other genomes (samples) are mapped on it sequentially. One genome from each individual is mapped at a time on the reference genome afterwards. If the same genomic segment is present in the reference (starting genome) and the sample (being considered for mapping) genomes then the segment from reference genome will be kept in the pan-genome. If there are segments which are not present in the reference genome but only in sample genome then they are extracted and assembled. These newly assembled genomic sequences are then mapped back onto the reference genome. This whole process allows creation of one non-redundant pan-genome. This approach is computationally less intensive in terms of time and memory because whole-genome de-novo assemblies are not required for this process.

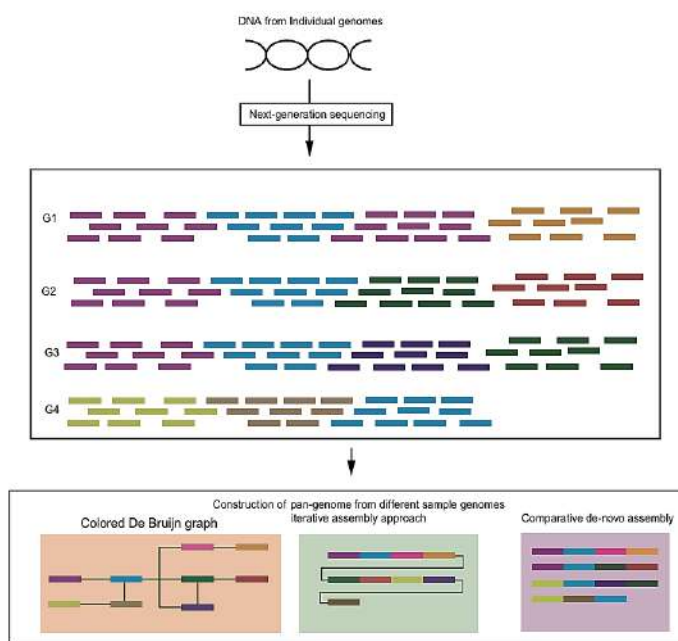


Figure 5. Four different genomes (represented by G1, G2, G3, and G4) giving rise to a pan-genome by three different genome assembly approaches are shown.

Each of these genomes is composed of different distinct DNA segments represented with different colors. Same color is used to represent the presence of same segment in all genomes. In the colored De Bruijn graph, any genome can be assembled back by tracing the edges of the graph. In the second approach, G1 is used as a reference genome and every other genome is compared with it and variable genome segments are then added to it sequentially. This forms a non-redundant pan-genome. In the *de novo* assembly approach, the genomes are assembled individually which are comparable to each other through whole-genome alignments.

PANGENOME ANALYSIS TOOL

Most of the software tools were developed initially for analysis of prokaryotic pan genomes and have guided the workflows and pipelines being used in the current pan-genomics analysis tools. However, all of the tools differ from each other in their functional performance including the methods used for orthologous genes identification, SNPs identification, phylogenetic analysis, and profiling of pan-genomes structures (core/dispensable/species specific genes identification). Summary of the available pan-genomics analysis tools is listed in Table 1.

Table 1: Summary of available pangenome analysis tools

Tool	Description
PGAP	Performs five analytical functions: cluster analysis of functional genes, pangenome profile analysis, genetic variation analysis of functional genes, species evolution analysis and function enrichment of gene clusters
PanGP	Requires orthologous gene clusters computed by programs such as OrthoMCL or PGAP and performs scalable pangenome analysis producing core genome, pangenome and new genes curves. It also implements two subsampling algorithms, which alleviate the computational burden of analysis of very high number of samples. It also has a user-friendly graphical user interface
Micropan	Package which offers a set of tools designed for pangenome analysis written in R programming language. R is a language of choice for a range of bioinformatics analyses and Micropan

	allows integration of pangenome and additional analyses within a single programming language environment
GET_HOMOLOGUES	Performs customizable genome analysis and is targeted for non-bioinformaticians. It enables clustering of orthologous genes using multiple algorithms and filtering parameters. Theoretical core gene and pangenome size curves can also be generated.
PanSeq	An online tool for analysis of core and accessory genomic regions. As a web server, it is platform independent and makes use of NCBI resources. It has three main modules Novel Region Finder (NRF), Core and Accessory Genome Finder (CAGF) and Loci Selector (LS)
SplitMem	Generates compressed coloured <i>de Bruijn</i> graph of the pangenome. In the graph, nodes represent sequences which are common or unique within the population, and edges are the branch points between common or sample specific sequences
ITEP	Generates and curates protein families. It can curate protein families, compute similarities to externally defined domains, analyse gene gain and loss and generate draft metabolic networks

CASE STUDIES

Case study No. 1:

The tomato pan-genome uncovers new genes and a rare allele regulating fruit flavour. (Gao *et al.*, 2019).

Key findings:

Tomato pan-genome was developed from 725 geographically and phylogenetically diverse accessions with Heinz 1706 as reference genome and lead to identification of rare allele and PAVs (Presence or absence variations).

- The pan-genome captured 4,873 additional genes not in the reference genome.
- Identified a rare allele: Analysis resulted in the identification of a 4-bp substitution in the regulatory region of the *TomLoxC* gene modifying the **tomato fruit flavor**.

- c) The modelling of the tomato pangenome indicated it to be a **closed pangenome** with finite numbers of core and dispensable genes.

Case study No. 2:

RPAN: rice pan-genome browser for ~3000 rice genomes (Sun *et al.*, 2017)

The cultivated rice, *Oryza sativa* L., is one of the major food sources for the world and a model organism in plant biology. The rice pan-genome, the genome of rice species rather than an individual, has been constructed from 3K rice genomes with a medium sequencing coverage about 15X. This pan-genome contains ~370Mbp IRGSP genome and ~260Mbp novel sequences, which are almost the same size as an individual rice genome.

Rice Pan-genome Browser (RPAN), as a tool to search and visualize the rice pan-genome derived from 3K Rice Genome Project. RPAN contains a database of the basic information of 3010 rice accessions, including genomic sequences, gene annotations, PAV information and gene expression data of the rice pan-genome. At least 12 000 novel genes absent in the reference genome were included. RPAN also provides multiple search and visualization functions. RPAN can be a rich resource for rice biology and rice breeding.

APPLICATION OF PLANT PAN-GENOMES

Table 2. Applications of plant pan-genomics

S.No.	Applications	Attributes
1.	Genetic mapping approaches and plant pan-genomics	1. Assessment of the gene content. 2. Estimation of additional whole genome sequences. 3. Optical mapping. 4. Long read sequencing. 5. Re-establishment of repetitive regions.
2.	Pan-genomics in crop diversity	1. Recognition of variants. 2. Basis for improvement of agronomic traits.
3.	Pan-genomics in adaptations to climate changes	1. Production of climate adapted cultivars. 2. Food security. 3. Identification of stress resistant traits.

4.	Pan-genomics in plant breeding	1. Mapping of quantitative trait loci (QTLs). 2. Exploration of single nucleotide polymorphism (SNPs). 3. Investigation of candidate genes for releasing improved varieties.
5.	Pan-genomics in production of desirable traits	1. Production of hybrid cultivars. 2. Exploitation of PAVs/CNVs in crop breeding.

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ROLE OF BIOFERTILIZERS AND BIOPESTICIDES IN SUSTAINABLE AGRICULTURE

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Introduction

The growing demand for sustainable agricultural practices has highlighted the significance of biofertilizers and biopesticides as eco-friendly alternatives to chemical inputs. Biofertilizers enhance soil fertility and plant growth by facilitating nutrient availability through microbial activity, while biopesticides offer effective pest control with minimal environmental impact. These biological agents contribute to improved crop productivity, soil health, and ecological balance, making them essential components of sustainable farming systems. Despite their numerous advantages, challenges such as lack of awareness, inconsistent performance, and poor regulatory support hinder their widespread adoption. Strengthening research, extension services, and policy frameworks is crucial to promote the use of biofertilizers and biopesticides in mainstream agriculture.

Sustainable agriculture is the backbone of food security, environmental protection, and economic viability. As the world moves toward eco-friendly farming practices, the use of biofertilizers and biopesticides has emerged as a vital alternative to chemical-based inputs. These biological products not only enhance soil fertility and crop protection but also reduce the environmental and health hazards associated with synthetic fertilizers and pesticides.

What are Biofertilizers and Biopesticides?

- Biofertilizers are substances containing living microorganisms, which, when applied to seeds, plant surfaces, or soil, promote plant growth by increasing the availability or

supply of primary nutrients. Examples include Rhizobium, Azospirillum, Azotobacter, Phosphate-Solubilizing Bacteria (PSB), and Mycorrhiza.

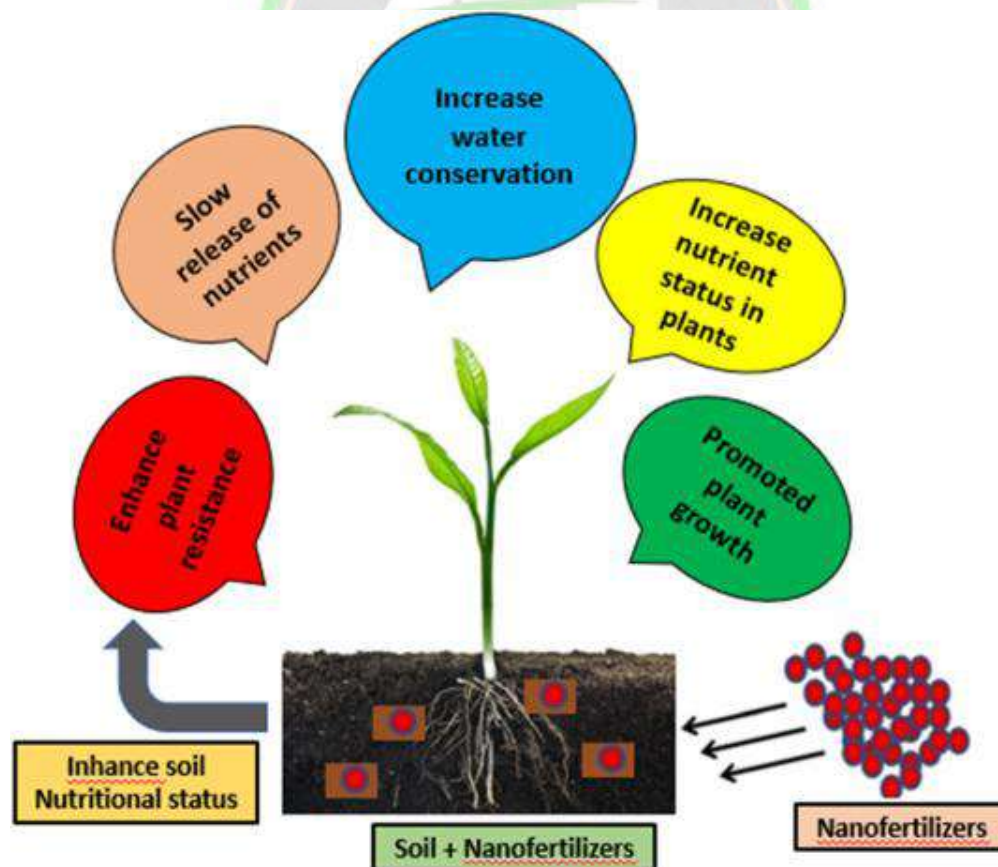
- Biopesticides are natural substances or microbial agents that control pests, pathogens, or weeds. These include *Bacillus thuringiensis* (Bt), *Trichoderma* spp., *Beauveria bassiana*, and neem-based products.

Role in Enhancing Soil Fertility and Crop Productivity

Biofertilizers improve soil health by:

- Fixing atmospheric nitrogen (e.g., Rhizobium in legumes).
- Solubilizing insoluble phosphates for plant uptake.
- Enhancing root growth and nutrient absorption through symbiotic relationships (e.g., mycorrhizae).

They are cost-effective, reduce dependency on chemical fertilizers, and help maintain a balanced ecosystem. Long-term use improves soil texture, organic content, and microbial diversity — essential for sustainable farming.



Biofertilizers and biopesticides offer several added advantages that make them vital for sustainable agriculture. Biofertilizers help restore natural soil flora, support organic certification, and reduce greenhouse gas emissions by minimizing the use of synthetic nitrogen fertilizers. They also enhance plant resilience to abiotic stresses like drought and salinity, thereby supporting long-term soil and crop health. On the other hand, biopesticides are safe for non-target organisms such as pollinators and beneficial soil fauna, and they decompose rapidly, leaving no harmful residues on crops. Their compatibility with Integrated Pest Management (IPM) strategies reduces chemical dependency, and their residue-free nature enhances the export potential of agricultural produce. Collectively, these biological inputs not only improve productivity but also promote a more eco-friendly and economically viable farming system.

Role in Eco-Friendly Pest Management

Biopesticides are effective in managing various insect pests and diseases without leaving harmful residues on crops or soil. Their advantages include:

- **Target specificity:** Only harmful pests are affected, preserving beneficial insects.
- **Biodegradability:** They break down quickly and do not pollute soil or water.
- **Resistance management:** Using biopesticides reduces the risk of pests developing resistance, as often seen with chemical pesticides.

Farmers using biopesticides also report healthier crop growth and improved yields due to reduced stress from pest attacks.

Advantages Over Chemical Inputs

Parameter	Biofertilizers/ Biopesticides	Chemical Inputs
Environmental Impact	Eco-friendly and biodegradable	Harmful to soil, water, and air
Soil Health	Improves long-term fertility	Depletes organic matter
Human Health	Safe and non-toxic	Can cause serious health issues
Cost	Low cost, especially for smallholders	Expensive, especially with repeated use

Challenges in Adoption

Despite their benefits, widespread adoption of biofertilizers and biopesticides faces challenges:

- Lack of awareness among farmers.

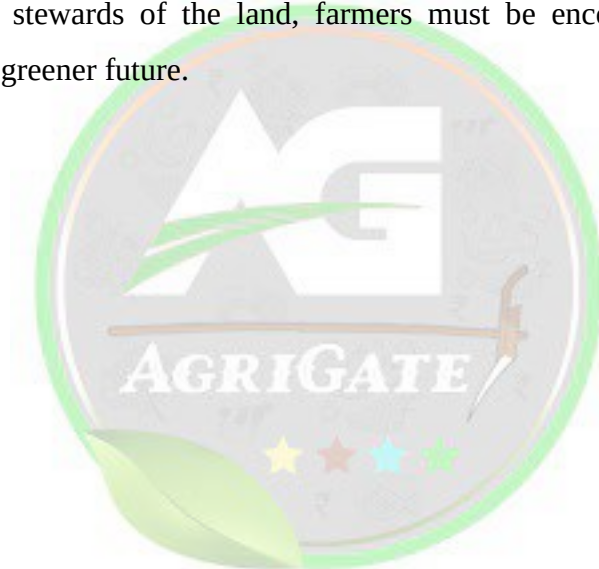


- Limited shelf life and storage issues.
- Inconsistent performance under varying climatic conditions.
- Poor regulatory framework and quality control in some regions.

To overcome these, there is a need for training programs, demonstration plots, subsidies, and stronger institutional support.

Conclusion

Biofertilizers and biopesticides play a crucial role in promoting sustainable agriculture by improving soil health, enhancing crop productivity, and reducing the ecological footprint of farming practices. With increased research, farmer education, and supportive policies, these biological tools can help transform modern agriculture into a more resilient, eco-friendly, and productive system. As stewards of the land, farmers must be encouraged to embrace these sustainable inputs for a greener future.



SEED COATING TECHNOLOGY

Article ID: AG-VO5-I05-60**Karadi Arpitha¹, Vangala Navya¹ and Dr. K. Ravikumar²**

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Abstract

Seed coating technology is an innovative and increasingly essential agricultural practice aimed at enhancing seed performance, protection, and uniformity in crop establishment. By applying a thin layer of materials—including polymers, fertilizers, pesticides, bio-inoculants, and growth stimulants—onto the seed surface, this technique improves germination rates, seedling vigor, and early plant development. Seed coatings provide a targeted delivery system for agrochemicals, reduce environmental impact, and support sustainable farming by minimizing the overuse of inputs. The technology also facilitates precision planting by improving seed flowability and visibility. As agriculture faces growing challenges from climate change, soil degradation, and the need for higher productivity, seed coating offers a promising solution for improving crop resilience, resource efficiency, and overall yield. Future advancements are expected to focus on biodegradable materials, smart-release formulations, and coatings tailored to specific environmental stresses, making seed coating a key component of next-generation sustainable agriculture.

Keywords: Seed coating, film coating, pelleting, encrusting

Introduction

A cutting-edge method of farming, seed coating technology is intended to increase crop establishment and seed performance. It entails putting external substances on the surface of seeds, including polymers, fertilizers, insecticides, micronutrients, and advantageous microbes.

This covering can be customized to safeguard against pests and illnesses, promote germination, and give the seedling direct access to vital nutrients. Higher crop yields and more environmentally friendly farming methods are facilitated by seed coating, which also enhances seed handling and planting efficiency and encourages uniform emergence and early growth.

Seed Coating

Seed coating is a technique that involves applying a thin, uniform layer of materials around a seed to improve its growth, protection, and handling characteristics.

Objectives of Seed Coating

1. Improve seed performance in a range of field scenarios.
2. Increase the accuracy of seed handling and planting.
3. Guard seeds from diseases, pests, and unfavourable conditions.
4. Provide growth promoters and vital nutrients to the germination spot.
5. Use size standardization to facilitate consistent seed spacing and planting.

Types of seed coating

1. **Film Coating:** A thin, consistent covering of polymer and chemical ingredients is called a film coating. The size and shape of the seed remained unchanged. preserves the germination rate and seed look normal. frequently used to apply colors, fungicides, or insecticides.
2. **Encrusting:** More material is added by encrusting than by film coating. slight variation in the weight and size of the seed. improves the ability to control the spacing and depth of sowing. improves the supply of nutrients and seed protection.
3. **Pelleting:** Seeds are coated with a thick layer to completely change shape and size. Frequently seen in seeds with small or irregular shapes (e.g., lettuce, carrots). allows for highly precise mechanical planting. Often includes growth stimulants and fertilizers.

Materials Used in Seed Coating:

- a) **Polymers:** Binders that ensure adhesion of coating to the seed (e.g., PVA, latex).
- b) **Colorants:** For seed identification and branding.
- c) **Pesticides/Fungicides:** Protection from soil-borne pests and diseases.
- d) **Micronutrients:** Iron, zinc, manganese for early seedling development.
- e) **Biofertilizers:** Rhizobium, Azospirillum, mycorrhizae for promoting plant growth.
- f) **Hydrogels:** Improve water retention around seeds.

Mode of action (Seed coating)

1. Fungicidal and insecticidal coating for protection

As soon as the seed is sown, the pesticide layer shields the seed and growing seedling. The compounds create a protective halo as they permeate into the nearby soil microenvironment. Fungi found in soil, such as *Rhizoctonia*, *Pythium*, and *Fusarium*. Insects that attack the seed early on, such as wireworms and cutworms.

2. Controlled Nutrient Delivery

During germination and early growth, the seed has instant access to vital components owing to the gradual, near-seed release of coated nutrients. It also enhances root establishment by lowering volatilization or nutrient leaching.

3. Improved Germination and Vigor

Plant growth stimulants encourage quicker cell division and elongation in the embryo; beneficial bacteria infiltrate the rhizosphere, promoting nutrient uptake and disease resistance; and polymers keep the seed's surrounding environment moist, which improves water uptake.

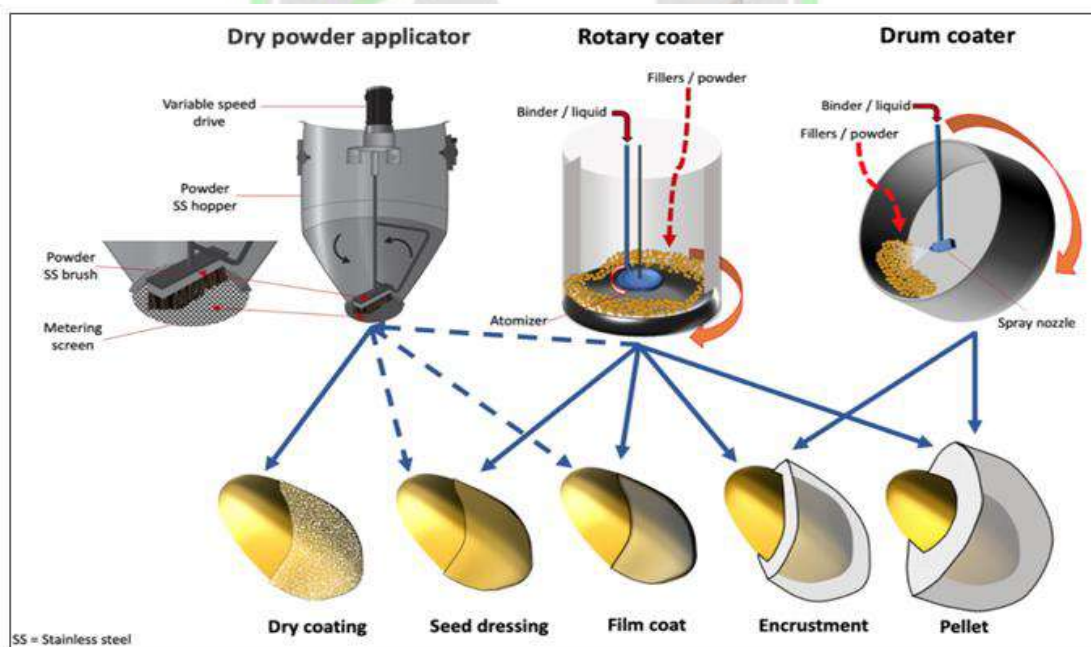


Figure 1. The three major types of seed coating equipment: dry powder applicator, rotary coater and drum coater used to produce five seed coatings: dry coating, seed dressing, film coat, entrustment and seed pellet. drum coater used to produce five seed coatings: dry coating, seed dressing, film coat, entrustment and seed pellet (Afzal *et al.* 2020).

Uniformity and Plant Stand

Coating-induced homogeneity in seed weight and size enhances mechanical sowing accuracy, depth control, and spacing. results in more consistent plant growth and emergence.

Identification and Traceability

Colorants in seed coatings aid in the identification of treated seeds, which is crucial for safety and regulatory purposes, and help to avoid unintentional ingestion (some coatings are purposefully dyed red or blue).

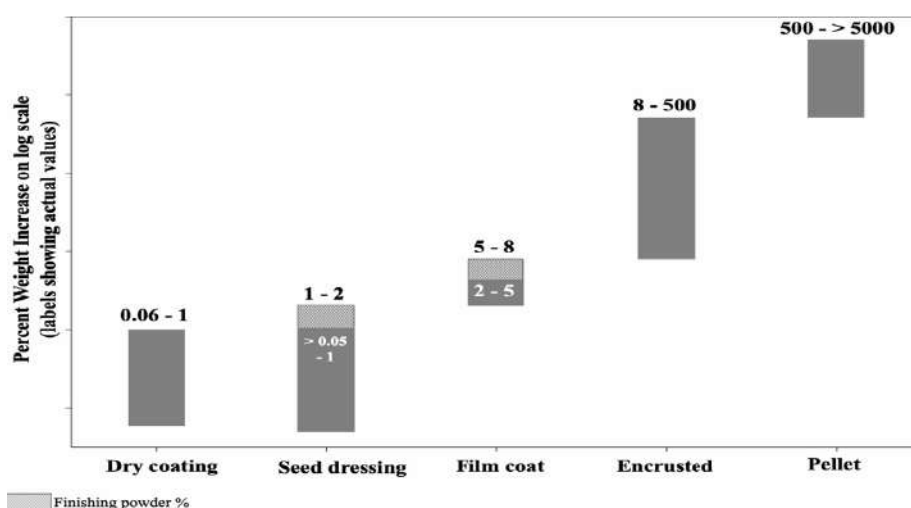


Figure 2. Percent weight increase after dry coating, seed dressing, film coat, entrustment and seed pellet technologies. The grey shaded bar for seed dressing and film coat is addition of a finishing (Afzal *et al.* 2020).

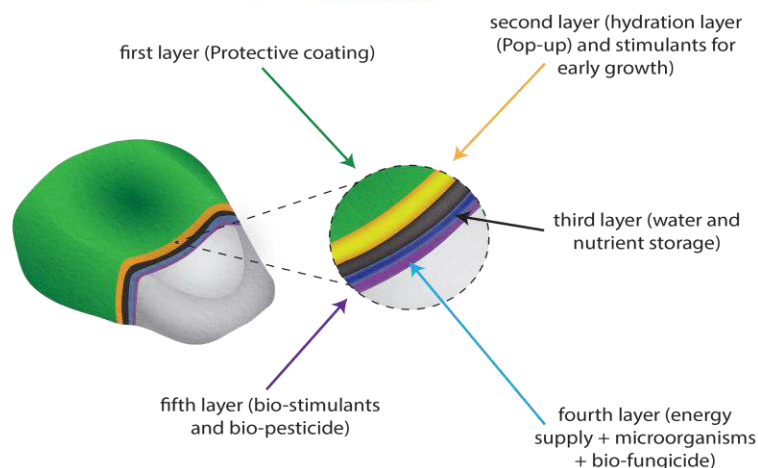


Figure 3. Organic Seed Coating for Food Security (<https://facagro.com/2017/02/01/Organic-seed-coating-for-food-security/future-agro-challenge>)

Benefits of Seed Coating:

1. A greater rate of germination
2. Lower input costs (specific chemical use)
3. Less harmful to the environment than widespread fertilizer and pesticide use.
4. Improved establishment of seedlings in stressful environments (salinity, drought).
5. Precision agriculture integration.

Limitations of Seed Coating:

1. Germination may be impacted by improper formulation
2. Seed respiration and imbibition **must be compatible** with the coating
3. If coated seeds are not adequately prepared, storage stability may become a problem

Conclusion

An important development in contemporary agriculture is seed coating technology, which provides an accurate and effective way to improve seed performance and early plant development. It enhances germination rates, seedling vigor, and crop uniformity while lowering input waste and environmental impact by incorporating nutrients, protective agents, and biological stimulants directly onto the seed surface. By reducing excessive pesticide usage and facilitating improved resource management, this technique promotes sustainable farming.

Future aspects

The future of seed coating technology lies in the development of eco-friendly, biodegradable coatings, the use of smart delivery systems that respond to environmental cues, and the incorporation of improved bio-stimulants and microbial consortia. Crop responsiveness and coating efficiency will be further improved by integration with nanotechnology and precision agriculture instruments. Seed coatings designed for stress resilience such as drought, salt, and temperature extremes will be essential for maintaining food security as climate change continues to impact agriculture worldwide.

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RENEWABLE ENERGY-BASED FARM ELECTRIC FENCING

Article ID: AG-VO5-I05-61***Manisha Sahu, H.L. Sonboir and Deepika Sahu**

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Introduction

The Solar Perimeter Security Electric Fence is a modern, eco-friendly alternative to traditional fencing. It provides reliable protection for crops and property by deterring animals through safe electric pulses. This system helps significantly reduce losses caused by wildlife, ensuring enhanced security and peace of mind for farmers and landowners. Ele Alert detects fence breaches using sensors and alerts nearby communities to prevent human-animal conflict (Wijesinghe *et al.*, 2011). Martino *et al.*, 2006 introduces fundamental concepts of electric fence technology and present a new design procedure for a livestock electric fence energizer circuit and impulse transformer. Solar electric fencing has been installed on the boundary wall of the girls' hostel at the Dau Kalyan Agricultural College, Bhatapara for protection against monkeys.

HOW DOES THE SOLAR ELECTRIC FENCE SYSTEM WORK?

When an animal or human touches the electric fence, they receive a brief, sharp, and safe electric shock that causes no physical harm. This creates a strong psychological deterrent, as intruders learn to avoid the fence after one encounter. Over time, its presence alone becomes an effective barrier—even when powered off. Additionally, the system can detect faults such as wire cuts or short circuits, triggering an alarm in case of tampering.

Working Principle

The solar energy is converted to electrical energy by photo-voltaic. (PV) cells this energy is stored in batteries during the day time in order to utilized whenever required.

Component of a solar fencing system

- Battery

- Charge control unit (CCV)
- Energizer
- Fence voltage alarm
- Photo-voltaic module



Solar Electric Fencing at Girls Hostel of Dau Kalyan Singh College of Agriculture and Research Station, Bhatapara

Advanced Features of the Solar Electric Fence

- The electric fence can be installed alongside existing fences, except barbed wire fences.
- Existing fence posts can be reused, provided corner and end posts are structurally strong.
- The electric shock is safe and does not cause physical harm to animals or humans.
- The Solar Electric Fence System complies with both national and international safety standards.
- Solar energizers are tested and certified by ETDC, Government of India.

Why Choose Solar Electric Fencing Over Conventional Fences

Safe and Durable Design: Uses plain high-tensile wire instead of barbed wire, ensuring long life with minimal wear and tear, and safety for both humans and animals.

Flexible and Customizable: Allows for selective barriers (e.g., elephant-proof fencing that permits smaller animals) and adapts to various terrain with posts spaced 6–8 meters apart.



Highly Effective and Widely Used: Proven success in over 165 countries as the most effective method for deterring wild animals.

Independent Power Source: Operates on battery powered by solar energy, eliminating dependence on a regular electricity supply.

Easy to Install and Maintain: Quick to construct, requires minimal maintenance, and offers long-term reliability.

Portable and Adaptable: Can be modified, extended, shifted, or reinstalled elsewhere without material loss or extra labor.

Areas Where Electric Fencing Is Effective

Agricultural, Forestry, and Plantation Use: Widely used to protect crops and property from animals and intruders, offering a reliable solution in rural and remote areas.

Industrial Applications: Provides robust security against theft, pilferage, arson, and sabotage; can be integrated with alarms, sirens, and floodlights for enhanced protection.

Domestic Security: Sleek and aesthetic wall-top systems ideal for residential compounds, rooftops, farmhouses, and apartments, addressing growing urban security needs.

Essential Steps for Electric Fence Maintenance

Ensure Complete System: Verify that your solar electric fence includes all necessary accessories and components for optimal performance.

Protect the Energizer: Keep the Energizer and control unit sheltered from rain, ideally housed in a secure area.

Clean Solar Panel: Regularly clean the solar panel's surface to remove dust and debris for efficient energy absorption.

Proper Panel Mounting: Install the solar panel in the North-South direction at a 15-degree angle for maximum sunlight exposure.

Earthing and Vegetation Maintenance: Use quality Super Earth Kits for proper earthing and regularly clear vegetation around the fence to maintain performance.

Proper Battery Maintenance for Electric Fencing

Clean Terminals Regularly: Keep battery terminals clean and apply petroleum jelly periodically to prevent corrosion.

Maintain Specific Gravity: Ensure the battery's specific gravity stays between 1150 - 1250 for optimal performance.

Add Distilled Water: Regularly add distilled water to maintain the electrolyte level in each cell of the battery.

Proper Positioning: Keep the battery upright on a wooden plank to prevent damage.

Avoid Adding Acid: Never add acid to the battery, as it can cause damage.

Initial Charging & Usage: Ensure proper initial charging of the battery and avoid leaving it unused for more than one month.

Benefits of the Electric Fence System

Non-lethal System: Safe and effective, causing no harm to animals or humans.

Cost-Effective: Requires fewer materials and labor compared to traditional fencing methods.

Easy to Construct: Built with lighter, simpler materials for quick installation.

Long-Lasting: Designed to endure with reduced physical wear and tear.

Universal Application: Effectively contains all types of animals while deterring predators and trespassers.

Enhances Existing Fences: Improves the durability and lifespan of traditional fences by adding electrified wires or offsets.

Low Maintenance and Stock Protection: Requires minimal upkeep and ensures less harm to animals, even under stress from wild animals or fires.

Conclusion

The cost of the solar electric fencing unit was Rs. 7,500, and the installation of the wire cost approximately Rs. 15,000. The cost of the solar electric fencing depends on the length of the wire. The Solar Perimeter Security Electric Fence offers a reliable, eco-friendly solution for protecting property and crops. With low maintenance, cost-effectiveness, and versatility, it provides lasting security and peace of mind.

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BIOLOGICAL DIVERSITY ACT, 2002

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Introduction

The Biological Diversity Act, 2002 is enacted by the Parliament of India for the preservation of biological diversity in India and provides the mechanism for equitable sharing of benefits arising out of the use of traditional biological resources and knowledge. Biodiversity has been defined under Section 2(b) of the Act as "the variability among living organisms from all sources and the ecological complexes of which they are part and includes diversity within species or between species and of eco-systems". The International day for Biological Diversity is celebrated every year on 22nd of May. There is need for understanding of biodiversity resources and its threats and the acts that preserve biodiversity in India. This paper will discuss about brief history and provisions of the act and national biodiversity authority of India.

Salient Features of the Act

The act is enacted with an objective to conserve biodiversity and fair, equitable share of the profits/ benefits arising out of use of biodiversity. There are 12 chapters provided in the act. The key provisions of act include

- The transfer of genetic material from India to foreign countries is prohibited without proper approval from National Biodiversity Authority (NBA).
- No person can claim IPR or patent over biodiversity in India.
- The share of benefits related to use of biodiversity including transfer of technology, monetary returns and joint research developments should be fair and equitable.
- The measures for conservation of biodiversity and taking up projects for conservation of biodiversity.

- The development and use of GMO's are regulated.

National Biodiversity Authority:

NBA is statutory autonomous body, works under Ministry of Environment and forests, GoI. It is established in year 2003. Any grievance arising from the determination of benefit sharing or from any order issued by the National Biodiversity Authority or a State Biodiversity Board under the provisions of this Act shall lie before the National Green Tribunal (NGT) for adjudication. There are State biodiversity boards created and maintained by NBA across the country.

India's Updated National Biodiversity Strategy and Action Plan is aimed at reducing threats to biodiversity, meeting needs through sustainable use and benefit-sharing.

Penalties:

If a person, violates the regulatory provisions will be "punishable with imprisonment for a term which may extend to five years, or with fine which may extend to ten lakh rupees and where the damage caused exceeds ten lakh rupees, fine may commensurate (be in proportion) with the damage caused, or with both."

- Section 6 of Biological Diversity Act, 2002



Lion-tailed macaque (Macaca silenus), Nilgiri tahr (Nilgiritragus hylocrius) and Malabar civet (Viverra civettina) some of the significant Endemic species of India (found in Western Ghats)

Recent developments pertaining to biodiversity in India

- The Union Budget has increased funding for the MoEFF & CC by nearly 10%, with specific boosts for forest fire management and biodiversity conservation initiatives. And union budget, 2025 likely to encourage ongoing green energy projects.

- Reliance Industries inaugurated 'Vantara', a 3,000-acre animal rescue and rehabilitation center in Jamnagar, Gujarat, housing over 2,000 animals across 43 species.
- Citizens and activists in Bengaluru are protesting the proposed felling of 368 trees in the Cantonment area for a commercial project, emphasizing the need to preserve urban green spaces.



- The Aravalis region is witnessing an influx of rare migratory birds, including Indian Pittas and Paradise Flycatchers, highlighting the area's significance as a bird habitat
- In Odisha's Nabarangpur district, a unique plantation project integrates ecological conservation with Odia linguistic heritage by planting saplings corresponding to each letter of the Odia alphabet- 'Barnamala Udyan'.
- Karnataka designated the Hesaraghatta grasslands near Bengaluru as the Greater Hesaraghatta Grassland Conservation Reserve, recognizing its ecological importance and role in water security.

Key forms of Biodiversity Exploitation

The biodiversity in India is usually exploited in areas of

- Agriculture and livestock breeding
- Forestry and Timber Extraction
- Hunting for meat, fur, traditional medicine (e.g., tiger for bones, rhinos for horns elephants for ivory & musk deers for scent).
- Over fishing of fresh water and marine water bodies.
- Exploitation of rare medicinal plants and aromatic plants



- Land conversion for roads, dams, mining operations leads to ecosystem fragmentation.

Sustainable solutions for conservation and reclamation of biodiversity

- Biodiversity-friendly agriculture (e.g. agroforestry, crop rotation)
- Legal protection of endangered species
- Community-based conservation models
- Access and Benefit Sharing (ABS) under the Biological Diversity Act, 2002
- Ecotourism to incentivize conservation through economic means.

Conclusion

India, with its diversified flora and fauna is home for very significant biodiversity in world. The Biodiversity act, 2002 aims at effective implementation of provisions, coupled with public awareness and community participation is vital for safeguarding India's biodiversity for current and future generations.





AGRI-STARTUPS AND THE YOUTH MOVEMENT IN FARMING

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Abstract

As agriculture faces the twin challenges of climate change and economic uncertainty, a new wave of young entrepreneurs is breathing life back into the sector. This article explores how youth-led agri-startups across India are transforming traditional farming through technology, innovation, and sustainable business models. From AI powered crop management to low-cost greenhouse solutions, these ventures are redefining the role of farming in a modern economy. By blending rural roots with digital tools, today's youth are not just cultivating crops they're cultivating a revolution. This is the story of how they're turning soil into gold.

Keywords: Agri-Startups, Youth Entrepreneurship, Agri-Tech Innovation, Sustainable Farming and Rural Development.

Introduction

For decades, farming in India was often viewed as a declining profession labor-intensive, underpaid, and less appealing to the modern generation. But in recent years, this perception has undergone a radical transformation. A new wave of youth-led agri-startups is infusing life back into the sector, combining modern technology with age-old practices to make farming more profitable, sustainable, and scalable.

These are not traditional farmers. They are engineers, MBAs, and social entrepreneurs who have chosen to return to the roots quite literally. Whether it's using drones to monitor crop



health or deploying AI to optimize irrigation, these young innovators are turning fields into business ventures and transforming agriculture into a forward-looking industry. It's a powerful reminder that when innovation meets intent, even soil can turn to gold.

The Rise of Agri-Entrepreneurship among Youth

There has been a noticeable shift in youth mindset over the past decade. While urban jobs still dominate, a growing number of young Indians are looking toward rural entrepreneurship not as a compromise, but as an opportunity. Agri-startups have emerged as a space where they can solve real problems, create social impact, and build sustainable businesses.

Government programs like:

- **Startup India,**
- **Rashtriya Krishi Vikas Yojana (RKVY-RAFTAAR),** and
- **Atal Innovation Mission**

have provided a much needed boost. Coupled with improved rural internet connectivity and access to e-commerce, young founders now find it easier to reach farmers, investors, and markets.

Technology Meets Tradition: Innovations Redefining Farming

Agri-startups are proving that farming doesn't have to be stuck in the past. Here are some key innovations:

- **Drones & IoT Sensors:** Monitor crop health, detect diseases early, and optimize fertilizer use.
- **Mobile Apps for Farmers:** Apps provide market price updates, weather forecasts, and best practices.
- **Hydroponics & Vertical Farming:** Soil-less farming methods that save water and space, ideal for urban and peri-urban areas.
- **Block chain for Supply Chain:** Ensures transparency and traceability in produce.

These tools help farmers reduce waste, cut costs, and improve yields—making agriculture more profitable and climate-resilient.

Success Stories of Youth-Led Agri-Startups

Several youth-founded agri-startups are making headlines:

- **DeHaat** (Founded by IIT grads): A digital platform connecting over 1 million farmers with agri-inputs, advice, and buyers.



- **Kheyti:** Offers low-cost greenhouse kits to small farmers, enabling year-round cultivation and increased income.
- **AgroStar:** A mobile app that delivers seeds, fertilizers, and farming solutions directly to rural areas.

These ventures are not just making money they're also solving core problems like rural unemployment, food insecurity, and lack of farmer knowledge.

Challenges on the Path

Despite the progress, youth in agri-startups face several hurdles:

- **Funding Gaps:** Early-stage investment is often hard to secure for non-tech or rural-focused ventures.
- **Market Access:** Reaching remote farmers and convincing them to adopt new tools requires patience and trust-building.
- **Policy Barriers:** Regulatory approvals and lack of infrastructure in villages can delay scaling.

However, the increasing support from incubators, government policies, and agri-focused VCs is helping bridge some of these gaps.

The Road Ahead: Growth Opportunities

Looking forward, several factors point to a bright future:

- **Venture capital** is flowing steadily into agri-tech (over \$1 billion invested in Indian agri-startups in recent years).
- **Agri-incubators** and university collaborations are offering mentorship, R&D support, and pilot land for testing innovations.
- **Export markets** are opening up for organic and specialty produce grown by startup-supported farmers.

With increasing consumer awareness and climate challenges, the demand for sustainable agriculture solutions is only going to grow putting youth-led startups in a key position.

Conclusion

India's agricultural sector is standing at a transformative crossroads. With technology in one hand and purpose in the other, today's youth are redefining what it means to be a farmer or an agri-entrepreneur. They are not just tilling land they are building platforms, creating jobs, solving real problems, and inspiring a generation.

The rise of agri-startups is more than just a business trend. It is a movement that blends innovation, impact, and inclusivity turning what was once seen as a “low-growth” sector into a powerhouse of potential. And at the heart of it all, are young visionaries turning soil into gold.

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AQUAMIMICRY: SMARTER, HEALTHIER, AND GREENER FISH FARMING

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Abstract

The rising global demand for aquatic organisms, driven by increasing consumption, has led to intensified aquaculture practices often reliant on chemical inputs that compromise environmental and animal health. In response, innovative and sustainable technologies are emerging to enhance culture systems. Among these, Aquamimicry presents a nature-based approach that mimics natural aquatic ecosystems to improve productivity and sustainability. This method utilizes carbon sources to stimulate the proliferation of beneficial probiotics, microalgae, and ultimately copepods natural prey organisms rich in essential nutrients. Shrimp feeding on copepods experience improved feed conversion ratio (FCR), enhanced digestibility, superior growth performance, and better muscle quality, while reducing the need for commercial feeds. Furthermore, probiotics play a critical role in nitrogen cycling by assimilating ammonia and other waste-derived nitrogen compounds into microbial protein, thereby improving water quality. These beneficial microbes also produce antimicrobial compounds that suppress pathogenic bacteria in both the shrimp gut and surrounding environment. Collectively, Aquamimicry offers a promising, eco-friendly strategy to enhance shrimp aquaculture efficiency, health, and environmental sustainability.

Key words: Aquamimicry, Biofloc technology, Fermented rice bran (FRB), Probiotics, Antinutritional factors, Copepods, Sustainable aquaculture, Microbial ecology, Natural feed sources

Introduction

Fish farming, or aquaculture, is a vital economic activity in many parts of the world. It

not only supports food security and provides livelihood opportunities, but also contributes significantly to global trade and foreign earnings (Deepak et al., 2020). As fish continue to be a preferred source of high-quality animal protein, their global demand is steadily rising—driving the expansion of aquaculture operations. However, with increased production comes increased challenges, such as disease outbreaks, overuse of chemicals, and environmental degradation. These issues not only harm ecosystems but also pose risks to consumer health and farm sustainability.

To address these concerns, researchers and farmers alike are turning to innovative, eco-friendly technologies that promote biosecurity, reduce chemical use, and cut production costs—particularly in shrimp farming. Several advanced approaches have emerged, including wastewater treatment strategies like bioaugmentation, algal pond systems, nanomaterials (e.g., nanofiber membranes and nano-adsorbents), aerobic fermentation, and intensive systems such as biofloc technology (Poonam et al., 2022)

Among these, Aquamimicry stands out as a novel, nature-inspired solution. Also known as Copefloc technology, it mimics natural aquatic ecosystems by encouraging blooms of zooplankton—especially nutrient-rich copepods—using fermented rice bran and probiotics. These copepods not only serve as a high-quality supplementary feed for shrimp and fish, but also support the growth of beneficial bacteria that help maintain optimal water quality.

The technique fosters phytoplankton and zooplankton blooms, replicating the conditions found in healthy natural ponds. The result? Enhanced growth, improved feed efficiency, and increased immunity in cultured shrimp—thanks to the abundance of live feed rich in essential nutrients like long-chain polyunsaturated fatty acids (LC-PUFAs), minerals, pigments, and amino acids such as taurine (Conceição et al., 2010; Biesebeke, 2018; Butto & Haller, 2016). One of the key advantages of Aquamimicry is the natural red coloring (astaxanthin) in shrimp, which significantly boosts their market value and earns them the label of “organic shrimp” (Poonam et al., 2022). Remarkably, this system requires no chemical additives or antibiotics. Instead, fermented rice bran nourishes zooplankton, while naturally occurring bacteria foster a balanced ecosystem enriched with pre- and probiotics (Nisar et al., 2022).

Pioneered in 2013 by Thai shrimp farmers Mr. Sutee Prasertmark and Mr. Veerasan Prayota Mornkul (Zeng et al., 2020), the Aquamimicry system is gaining global attention for its potential to revolutionize aquaculture—making it smarter, healthier, and greener.

Biofloc technology VS Aquamimicry technology

Aquamimicry and Biofloc are two innovative technologies that both aim to make aquaculture more sustainable and productive. While they share some basic principles—like relying on beneficial microbes and adding external carbon sources to boost microbial activity—they differ significantly in how they are managed and the organisms they benefit most.

Both systems work by adding a carbon source, such as rice bran or molasses, which helps beneficial bacteria grow. These microbes consume nitrogen waste (like ammonia from fish or shrimp excreta) and convert it into microbial protein—essentially turning waste into a usable nutrient. However, the way this process is managed differs between the two.

In Biofloc Technology, maintaining a specific carbon-to-nitrogen (C:N) ratio—usually around 15:1—is crucial for forming and **sustaining** the microbial floc. This requires constant monitoring and regular aeration to keep the floc suspended in the water column. Fish, which can filter and consume these tiny flocs, benefit the most from this system.

In contrast, Aquamimicry is more relaxed when it comes to C:N monitoring. While it also uses a carbon source to stimulate microbial and plankton blooms, it doesn't require precise C:N balance or continuous aeration. Instead of microbial floc, copepods—tiny, nutrient-rich zooplankton—form the primary feed source. These are ideal for shrimp, which lack specialized filtering organs and cannot consume biofloc efficiently. Copepods, being larger and more natural prey, fit perfectly into a shrimp's diet and digestive system.

So, while Biofloc is best suited for fish culture, Aquamimicry shines in shrimp farming, offering a more natural, low-input system that closely mimics pond ecosystems. It's a prime example of working with nature, not against it—making aquaculture smarter, healthier, and greener.

Shrimp Farming the Aquamimicry Way: A Step-by-Step Guide

Shrimp culture under the Aquamimicry system follows a nature-based approach, using smart strategies that mimic wild aquatic ecosystems. The process is broken down into four main stages: pond preparation, fermented rice bran preparation, shrimp stocking and culture, and post-harvest management. Here's how it works:

1. Pond Preparation: Setting the Stage for Nature to Take Over

- The pond is filled with water to a depth of 80–100 cm, using fine mesh filter bags (200–300 μ m) to screen out impurities and unwanted organisms.



- Probiotics are added to the water, and the pond bottom is lightly chain-dragged for a week. This helps mix the soil with probiotics and prevents harmful biofilm buildup.
- A combination of teaseed cake (20 ppm) and fermented rice bran (50–100 ppm) is added. The teaseed cake eliminates unwanted fish and eggs, while both ingredients help stimulate copepod blooms. Full aeration during this stage ensures proper mixing and dispersal.

2. Preparing Fermented Rice Bran (FRB): Fueling the Ecosystem

- Rice bran or wheat bran is used as the carbon source. It's mixed with water at a 1:5–1:10 ratio and inoculated with probiotics, then fermented under aeration for 24 hours.
- If the bran is powdered, it can be gradually poured into the pond. If crumbled, only the liquid portion (the upper layer) is used.
- The nutrients from the fermented rice bran encourage blooms of phytoplankton and zooplankton, particularly copepods, which form the natural food web for shrimp.

3. Stocking and Culturing Shrimp: Growing Naturally

- Shrimp are stocked at the post-larval (PL) stage, with densities ranging from 30 to 100 shrimp per square meter, depending on the system's intensity.
- FRB dosage varies: in extensive systems, it's added at 1 ppm, while intensive systems require 2–4 ppm. The increased copepod population becomes a rich, natural food source, reducing the need for supplementary feeds.
- After 15 days, gentle dragging of sediment is done to maintain bottom quality, followed by probiotic addition.
- In intensive systems, central drainage helps remove waste, which is then collected in sedimentation tanks—ideally two hours after feeding to avoid nutrient loss.

4. Post-Harvest Management: Resetting the System

- After harvest, the pond is drained and cleaned thoroughly to remove debris, excess organic matter, and black soil.
- Once cleaned, the pond is ready to begin the next eco-friendly culture cycle—continuing the loop of smart, sustainable shrimp farming.

By mimicking natural aquatic food chains and creating a self-sustaining ecosystem, Aquamimicry provides a healthier, more resilient way to farm shrimp—reducing feed costs, improving water quality, and promoting stronger, more valuable shrimp.

Fermentation, Probiotics, and Plankton: Natural Tools for a Sustainable Aquamimicry System

Aquamimicry harnesses the power of nature—through fermentation, probiotics, and plankton dynamics—to build a sustainable, efficient, and healthy aquaculture environment. Here's how each of these components plays a key role in transforming aquaculture into a greener and smarter system.

Fermentation Techniques: Unlocking Nutritional Potential

Fermentation is a powerful tool to enhance the nutritional value of plant-based feed ingredients by breaking down anti-nutritional compounds and increasing bioavailability of essential nutrients.

- Rice bran, although nutrient-rich, has high fiber, phytic acid, lipids, and ash, which can reduce its digestibility. Through fermentation, these compounds are minimized, improving the nutrient profile. Fermented rice bran (FRB) is created by mixing powdered rice bran, probiotics, and hydrolyzing enzymes in water and fermenting the mixture for 24 hours (Abiri et al., 2022).
- Soybean meal is another excellent protein source but contains anti-nutritional factors (ANFs) like tannins, saponins, trypsin inhibitors, and phytoestrogens. These can negatively affect aquatic organisms. Fermenting soybean meal not only removes ANFs but also boosts protein content and digestibility, making it a valuable alternative to fermented rice bran in aquamimicry systems.

Probiotics: The Microscopic Powerhouses

Probiotics—mainly beneficial bacteria—play a central role in aquamimicry. These microorganisms:

- Inhabit the gut of aquatic species, improving digestibility, nutrient uptake, and immune function.
- Compete with harmful pathogens in both gut and water, producing antimicrobial compounds and reducing disease outbreaks.
- Improve water quality by converting waste nitrogen into microbial biomass, ultimately supporting the growth of zooplankton such as copepods.

In aquamimicry systems, probiotics work synergistically with carbon sources (like FRB) to consume unused nitrogen (from waste and uneaten feed), forming flocs and supporting copepod populations—an essential natural feed for shrimp (Deepak et al., 2020).

Additionally, probiotics provide synbiotic effects, reduce harmful bacteria via quorum sensing interference, aid in bioremediation, and increase post-larval survival rates (Deepti, M et al., 2024).

Diverse Plankton Communities: The Natural Feed Chain

Aquamimicry encourages the bloom of plankton communities that mirror natural aquatic ecosystems. Among these, copepods are particularly valuable.

The three major types of copepods used in aquaculture include:

- Harpacticoid copepods – thrive in benthic environments; excellent for high-density cultures.
- Calanoid copepods – pelagic and naturally consumed by fish and shrimp larvae.
- Cyclopoid copepods – versatile species found in varied environments.

Studies show that larvae fed with copepods have higher DHA/EPA ratios compared to those fed with enriched *Artemia*, highlighting their superior nutritional quality (Shields, R. J et al., 1999; Stottrup, JG et al., 2003 & 2006). Their short lifespan, small size, and high energy content make them ideal as live feed.

Shrimp Growth and Health in Aquamimicry

When fermented rice bran is added to the pond, it acts both as a prebiotic and a carrier of probiotics. These stimulate the growth of microalgae and beneficial bacteria, forming the base of the food chain. Copepods bloom by feeding on these microalgae and bacteria, and in turn, become a natural, nutrient-rich food source for shrimp.

Copepods provide:

- High-quality proteins
- Essential fatty acids (EPA & DHA)
- Vitamins, minerals, and pigments

Shrimp that feed on copepods show:

- Improved feed conversion ratio (FCR)
- Higher nutrient bioavailability
- Faster growth rates

- Reduced dependence on artificial feeds

Ultimately, this leads to healthier shrimp, lower input costs, and a cleaner, more sustainable pond environment.

Building Stronger Shrimp: Immunity and Water Quality in Aquamimicry Systems

One of the most impressive advantages of Aquamimicry is its positive impact on shrimp health and immunity, as well as its ability to maintain excellent water quality—two key factors for sustainable and profitable aquaculture.

Stronger Immunity, Healthier Shrimps

Disease outbreaks, especially caused by *Vibrio parahaemolyticus*, are a major threat in traditional shrimp farming systems, often leading to sudden and complete mortality (Hong To et al., 2020; Intriago et al., 2023). However, studies have shown that in ponds managed with Aquamimicry technology, this harmful pathogen was completely absent, while it was present in conventionally managed ponds (Islam, M. S. et al., 2024).

Shrimp health is typically evaluated through histological analysis of the hepatopancreas, a vital organ responsible for digestion and nutrient absorption. In healthy shrimp, the hepatopancreas shows well-formed, regularly shaped tubules. In contrast, disease-affected shrimp exhibit swollen, discolored, and irregularly shaped tubules, indicating organ damage and poor health.

In Aquamimicry systems, the use of fermented rice bran (FRB) enriched with probiotics plays a crucial role in disease prevention. These beneficial microbes colonize the shrimp gut, pond water, and sediment, where they outcompete harmful bacteria by:

- Competing for nutrients and space
- Producing antimicrobial compounds that inhibit pathogen growth
- Enhancing shrimp immunity by supporting a healthy gut microbiome

Cleaner Water, Healthier Ecosystem

Shrimp excretion—especially ammonia—is one of the main contributors to poor water quality in traditional aquaculture systems. Ammonia accumulation can lead to stress, disease susceptibility, and even mortality in shrimp.

In Aquamimicry systems, the introduction of FRB along with probiotics has a powerful bioremediation effect:



- Probiotics utilize nitrogen from ammonia and convert it into microbial protein, significantly reducing toxic ammonia levels in the pond.
- This natural nitrogen recycling improves water clarity, maintains optimal dissolved oxygen (DO) levels, and supports the growth of beneficial plankton, including copepods.

Conclusion: Why Aquamimicry Works

Aquamimicry offers a nature-inspired, cost-effective, and sustainable alternative to traditional shrimp farming. It helps:

- Improve feed conversion ratio (FCR)
- Boost digestibility and nutrient bioavailability
- Enhance shrimp immunity and disease resistance
- Maintain better water quality
- Reduce production costs significantly

In conventional shrimp farming, feed alone accounts for nearly 60% of total production costs. Aquamimicry cuts this down by naturally producing copepods and microalgae, which serve as supplementary, high-quality nutrition. As shrimp feed on copepods, they receive essential proteins, fatty acids, and micronutrients—reducing the reliance on commercial feeds and promoting a more natural, balanced ecosystem.

Ultimately, Aquamimicry isn't just a technique—it's a smarter, healthier, and greener way forward for the future of aquaculture.

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USE OF SURFACTANTS IN AGRICULTURE

Article ID: AG-VO5-I05-65**D.K. Bagri¹, R. Kumari² and D.L. Bagdi^{3*}**

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Abstract

Surfactants are used in agriculture to enhance the effectiveness of pesticides, herbicides, and other agrochemicals. They improve the wetting, spreading, and penetration of these chemicals, leading to better coverage on plant surfaces and more efficient uptake. Surfactants improve absorption efficiency by multiple ways. In particular surfactants increase the foliar uptake of herbicides, growth regulators, nutrients and defoliant. Therefore, the choice of the surfactants in an agrochemical formulation is crucial. Surfactants include anionic, nonionic, amphoteric and cationic surfactants. This article describes the role, merit, demerit, precautions and properties of surfactants for agriculture uses.

Keywords Surfactant, anionic, formulation, hormones, pesticide, nutrients and foliar spray.

Introduction

Surfactants are compounds that reduce surface tension, allowing liquids like pesticides and fertilizers to spread more easily and effectively on plant surfaces and in soil. This improves the absorption of nutrients and chemicals by plants and enhances the efficiency of crop protection practices. Surfactants are an effective way to improve uptake of nutrients, growth regulators and herbicides. Plants put up many barriers to the retention, entry and transport of

herbicides. These barriers typically are greater for foliar-applied than for soil-applied herbicides. In addition, environmental conditions and plant factors (age, architecture, leaf morphology and leaf arrangement) may decrease herbicidal activity. Adjuvants are commonly used to improve herbicide performance. Spray solution adjuvants are available for a variety of purposes. Some of the more common uses include: 1. Antifoam or defoaming materials, 2. Compatibility agents to aid mixing herbicides in spray solutions, 3. Buffer solutions to change spray solution pH, 4. Foam markers and dyes, 5. Suspension aids to improve herbicide suspension in spray solutions, 6. Tank cleaners and neutralizers, and 7. Surfactants.

Surfactants are a specialized additive formulated to improve the performance of herbicides in spray solution. They are, by far, the most commonly used adjuvant for post emergence herbicides. Surfactants improve herbicide performance as a result of modifying one or more of the following spray solution characteristics: 1. Mixing, or emulsifying and dispersing oil-soluble and water-soluble molecules; 2. Coverage, or spreading and wetting on leaf surfaces; 3. Spray retention, or sticking on leaf surfaces; and 4. Absorption, or penetrating properties. Surfactants are amphiphilic molecules, meaning they have a hydrophilic (water-attracting) end and a hydrophobic (oil-attracting) end.

Types of Surfactants

- 1. Silicone Surfactants:** These are particularly effective at spreading and penetrating waxy plant surfaces, and are resistant to being washed off by rain.
- 2. Nonionic Surfactants:** These are commonly used as emulsifiers, wetting agents, and dispersing agents in agrochemical formulations.
- 3. Other Surfactants:** Newer surfactants like alkyl polyglycosides, ethoxylate saccharose esters, and dimethylethanolamine based esterquats are also being used in agrochemical formulations.

Mode of action

Herbicide spray solution droplets containing surfactant provide greater leaf surface coverage and a greater potential for herbicide absorption into the plant. The main barrier to herbicide movement into the plant is a waxy layer, called the cuticle that covers the entire plant surface. Its purpose is to prevent water loss. It also inhibits herbicide movement into the plant. Herbicides formulated or applied with surfactants reduce the surface tension of water and allow for more effective movement of the herbicide through the cuticle. The performance of most

surfactants results from three important factors: the herbicide, the weed species and environmental conditions. Herbicide.

Functions of surfactants

A. Enhancing Agrochemical Performance

- 1. Improved Adhesion and Spreading:** Surfactants reduce the surface tension of water, allowing agrochemical sprays to spread more uniformly across plant surfaces, ensuring better coverage.
- 2. Enhanced Penetration:** Surfactants help agrochemicals penetrate waxy plant cuticles and soil, facilitating their absorption by the plant or soil.
- 3. Increased Efficacy:** By improving coverage and penetration, surfactants increase the efficacy of pesticides, herbicides, and fertilizers, allowing for better pest control and nutrient uptake.
- 4. Reduced Drift and Runoff:** Surfactants can also help minimize spray drift and runoff, reducing environmental impact and improving precision of application.

B. Improving Soil Health and Water Management

- 1. Enhanced Water Infiltration:** Surfactants can improve water penetration in hydrophobic soils, promoting better moisture retention and nutrient absorption.
- 2. Soil Conditioners:** Surfactants can act as soil conditioners, improving soil structure and water-holding capacity.
- 3. Nutrient Availability:** By improving nutrient availability in the soil, surfactants contribute to healthier plants and higher yields.

C. Other Agricultural Applications

- 1. Foliar Fertilization:** Surfactants enhance the uptake of nutrients through foliar applications, improving the overall health and growth of crops.
- 2. Seed Treatment:** Surfactants can improve the adhesion of seed coatings, enhancing germination rates and early plant development.
- 3. Anti-transpirants:** In water-scarce conditions, surfactants can reduce water loss from plant surfaces, helping plants withstand drought stress.

Surfactants Used in Agriculture:

- 1. Nonionic Surfactants:** These are the most widely used in chemical crop protection are: Silwet L-77, Tween 80, Agri-Dex, Triton X-100 and Sorbitan derivatives

2. Biosurfactants: These are produced by microorganisms and are becoming increasingly Popular as a more sustainable alternative.

3. Other Examples:

I. Cetylpyridinium chloride (CPC): A cationic surfactant used in some pesticides.

II. Fatty acid esters: Used as emulsifiers or oiling agents in various applications, including agriculture.

III. Lecithin: A naturally occurring surfactant from egg yolk or soybeans.

IV. Oil soaps: Historically used to enhance pesticide performance.

V. Silicone surfactants: Used to improve adhesion and penetration, especially on crops with thick waxy leaves.

Functions of Surfactants in Agriculture:

1. Wetting and Spreading: Reduce the surface tension of water, allowing it to spread more evenly on plant surfaces and penetrate leaves.

II. Penetration: Help agrochemicals penetrate the waxy cuticle of plant leaves, allowing them **to** reach the inner tissues where they can act.

III. Adhesion: Improve the adhesion of agrochemicals to plant surfaces, reducing the risk of runoff or wash-off.

IV. Improved Agrochemical Effectiveness: Enhance the overall effectiveness of herbicides, insecticides, and fungicides by improving their application and absorption.

V. Soil Conditioners: Used to improve water infiltration and distribution in the soil, Promoting better moisture retention and nutrient absorption

Merits of Surfactant Use:

1. Enhanced Pesticide and Fertilizer Uptake: Surfactants help break down surface tension, allowing pesticides and fertilizers to spread evenly and penetrate plant surfaces more effectively.

2. Improved Water Penetration: Surfactants can enhance water infiltration and distribution in the soil, leading to better moisture retention and nutrient absorption.

3. Reduced Water Loss: Surfactants can create a thin film on plant surfaces, minimizing water evaporation and reducing stress during dry periods.

4. Precise Spraying: Surfactants can help control droplet size and deposition, reducing off-target movement and improving the accuracy of pesticide applications.

5. Potential for Biosurfactants: Biosurfactants, produced by microorganisms, offer a more environmentally friendly alternative to synthetic surfactants, with biodegradability and lower toxicity.

Demerits of Surfactant Use:

- 1. Potential Toxicity:** Some surfactants, particularly cationic ones, can be toxic to plants and other organisms.
- 2. Persistence and Environmental Impact:** Synthetic surfactants may not biodegrade easily and can persist in the environment, potentially harming soil and aquatic life.
- 3. High Cost:** While biosurfactants are more environmentally friendly, they can be more expensive to produce and may have lower yields compared to synthetic surfactants.
- 4. Foam Formation:** Some biosurfactants can cause excessive foam formation, which can be a problem in certain applications.
- 5. Difficulty in Obtaining Pure Substances:** Isolating and purifying biosurfactants can be Challenging.

Precautions

The following precautions should be taken during application of surfactants with herbicide, pesticide, growth hormones and nutrients etc

- 1. Personal Protective Equipment (PPE):** Always wear appropriate PPE, including gloves, eye protection, and protective clothing, when handling surfactants.
- 2. Ventilation:** Use surfactants in well-ventilated areas or outdoors. If ventilation is inadequate, wear respiratory protection.
- 3. Contact Avoidance:** Avoid inhaling mists, vapors, or sprays, and contact with eyes, skin, and clothing.
- 4. Safe Handling:** Handle containers with care to prevent spillage and damage.
- 5. Storage:** Store surfactants in a safe and secure location, away from children and pets.
- 6. Spill Management:** If a spill occurs, isolate the area, keep unnecessary personnel out, and ventilate the area.
- 7. Hygiene:** Wash hands thoroughly after handling surfactants, especially before eating, drinking, or smoking.
- 8. Environmental Protection:** Avoid releasing surfactants into the environment, such as drains.



- 9. Read Labels:** Always read and understand all safety precautions on the surfactant label before use.
- 10. Proper Disposal:** Disposal of surfactants should be done in accordance with local regulations.
- 11. Over application:** Avoid over applying surfactants, as this can lead to phytotoxicity (plant damage).
- 12. Compatibility:** Ensure that the surfactant is compatible with the pesticide or fertilizer it is being used with.
- 13. Specific Precautions:** Some surfactants, like silicone adjuvants, can increase the potency of spray mixtures and may lead to plant damage if used at high temperatures or with certain herbicides.

Conclusion

Surfactants in agriculture enhance the effectiveness of agrochemicals and improve water management by reducing surface tension, improving wetting and spreading, and increasing penetration into plant tissues and soil. They act as emulsifiers, prevent drift, and enhance adhesion, making agrochemicals more effective and reducing the need for frequent applications.

WEED CONTROL BY PLANT GROWTH REGULATORS

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Abstract

Weeds are unwanted plants that grow alongside cultivated crops and compete with them for resources like water, nutrients, light, and space. This competition can reduce crop yield, quality, and overall growth, making weeds a significant agricultural problem. Plant growth regulators can be used for weed control by mimicking or manipulating plant hormones, disrupting weed growth, and potentially causing death. Some PGRs, particularly auxins, are effective at controlling broadleaf weeds. These herbicides disrupt the normal growth patterns of weeds, leading to their demise.

Key words: Weed, nutrients, light, growth regulators and herbicides.

Introduction

Plant growth regulators (PGRs) can be used for weed control, particularly those mimicking auxin, a hormone that promotes plant growth. Examples include 2,4-D, which is used to target broadleaf weeds in crops. Other PGRs, like those that inhibit indoleacetic acid transport, can also be used for weed control. PGRs can be applied post-emergence for weed control in turfgrass. Plant growth regulators used for weed control in agriculture disrupt the normal growth and development of weeds, often by mimicking natural plant hormones or interfering with their

biosynthesis. This leads to various effects, including abnormal growth, tissue damage, and ultimately, death of the weed. In agriculture, the plant growth regulator 2,4-D is primarily used for weed control, specifically to target broadleaf weeds (dicotyledons) in monocotyledonous crops. It works by mimicking the natural auxin hormone, causing uncontrolled growth in weeds, ultimately leading to their demise.

Mechanism of weed control by growth regulators

1.Auxin Mimics (Herbicidal Auxins)

Certain PGRs, like 2,4-D, act as synthetic auxins, mimicking the natural hormone auxin. They disrupt the normal auxin signaling pathways in weeds, leading to excessive cell elongation, abnormal tissue development, and eventually, death of the weed. This is particularly effective against dicot weeds (broadleaf plants) in cereal crops.

2.Gibberellin (GA) Inhibition

Some PGRs, like triazoles, interfere with the synthesis of gibberellins, which are crucial for stem elongation and overall plant growth. By inhibiting GA production, these PGRs can reduce stem growth, leading to more compact and less competitive weeds.

3.Absciscic Acid (ABA) Modulation

Some PGRs, like those affecting ABA biosynthesis, can increase or decrease ABA levels in weeds. ABA plays a role in stress responses, and its altered levels can lead to stress-related physiological changes, impacting weed growth and survival.

4.Ethylene Interference

Ethylene is involved in various developmental processes, including fruit ripening and senescence. Some PGRs can interfere with ethylene production or action, potentially affecting weed development and competitiveness.

5. Other Mechanisms

Certain PGRs may also affect other aspects of weed physiology, such as cell division, photosynthesis, or stress tolerance, ultimately contributing to their control.

In essence, weed control with PGRs involves manipulating plant hormone levels or interfering with their biosynthesis to disrupt normal growth and development in weeds, leading to their suppression or elimination.

Types of growth regulators for Weed Control

- 1.Auxins:** Auxins are plant hormones that promote cell elongation and root formation, and are used in weed control by mimicking this effect in weeds.
- 2.Synthetic Auxins:** 2,4-D is a synthetic auxin that is widely used for broadleaf weed control in crops and lawns.
- 3. Inhibitors of Indoleacetic Acid Transport:** These PGRs interfere with the plants ability to transport auxin, leading to weed suppression.

Application of growth regulators for weed control

1. PGRs can be applied to the foliage of weeds or through the soil, depending on the specific product and its mode of action.
- 2.Post-emergence applications are common for controlling weeds in turfgrass.

Examples of PGRs used in Weed Control

- 1. 2,4-D (2,4-dichlorophenoxyacetic acid):** A synthetic auxin widely used for broadleaf weed control in lawns and crops.
- 2. Dicamba:** Another synthetic auxin, effective against a range of broadleaf weeds.
- 3. Picloram:** A powerful auxin-like herbicide used for perennial weed control.
- 4. Other PGRs:** Various other synthetic auxins and other PGRs are also used for specific weed control applications.

Merits of weed control by growth regulators

- 1. Increased selectivity:** PGRs can be more selective than other herbicides, targeting weeds without harming the desired crop.
- 2.Reduced soil residue:**Many PGRs are less persistent in the soil compared to other herbicides, minimizing long-term environmental impact.
- 3.Lower concentrations:**Effective weed control can be achieved with lower concentrations of PGRs compared to other herbicides.
- 4.Reduced labor and equipment costs:**Chemical weed control, including PGRs, can be more efficient than manual methods, reducing labor and equipment requirements.
- 5. Flexibility in weed management:** Herbicides, including PGRs, offer flexibility in choosing a weed management system.
- 6. Improved control of perennial weeds:** Some herbicides can effectively manage perennial weeds, which are difficult to control with other methods.

7. Reduced soil disturbance: Herbicide application can minimize soil disturbance compared to tillage, which can be beneficial for soil health.

8. Reduced dependence on weather and human labor: Herbicides can provide weed control regardless of weather conditions and reduce the reliance on human labor.

Demerits of weed control by growth regulators

1.Potential for crop damage:Incorrect application or use of the wrong PGR can lead to crop damage.

2.Risk of rebound growth:After a period of regulation, some plants may store energy and experience a surge of growth, known as a rebound effect.

3.Environmental concerns:Herbicide runoff can contaminate water sources and affect non-target organisms.

4.Development of herbicide resistance:Prolonged use of the same herbicide can lead to weeds developing resistance, reducing its effectiveness.

5. Overregulation can stress turf: Excessive use of plant growth regulators can stress turf, making it more susceptible to diseases.

6. Discoloration and other aesthetic issues: PGR applications can cause discoloration or other aesthetic problems in turf.

7. Not all PGRs are effective on all weeds: The effectiveness of a PGR can vary depending on the weed species and other factors.

Conclusion

In agriculture, the plant growth regulator 2,4-D is primarily used for weed control, specifically to target broadleaf weeds (dicotyledons) in monocotyledonous crops. It works by mimicking the natural auxin hormone, causing uncontrolled growth in weeds, ultimately leading to their demise.

MICROBIAL ASTAXANTHIN FOR FOOD AND FEED APPLICATION

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Abstract

Astaxanthin (AXT) is a naturally occurring ketocarotenoid with potent antioxidant, anti-inflammatory, and immune-boosting properties. It is widely used in the food and feed industries for its pigmentation effects and health benefits. While traditionally sourced from marine organisms, microbial production using *Haematococcus pluvialis*, *Phaffia rhodozyma*, and certain bacterial strains offers a more sustainable and scalable alternative. This review examines the biosynthesis, production methods, and industrial applications of microbial astaxanthin in human food and animal feed. Furthermore, it discusses its nutritional and functional benefits, safety considerations, and future prospects for biotechnological advancements. By leveraging microbial biotechnology, astaxanthin production can be optimized to meet the growing demand for natural and health-promoting carotenoids.

Introduction

Astaxanthin (AXT) is a red-orange carotenoid pigment naturally produced by various microorganisms, particularly microalgae, yeast, and some bacterial species. It is renowned for its powerful antioxidant capabilities, surpassing those of other carotenoids like β -carotene and lutein. Due to its health-promoting properties, AXT has found extensive applications in the food, nutraceutical, and animal feed industries (Banerjee and Ramaswamy, 2022).

Traditional sources of astaxanthin include marine organisms such as krill, shrimp, and salmon. However, the extraction of AXT from these sources is costly and unsustainable, leading to a shift towards microbial production. Microorganisms such as *Haematococcus pluvialis* (a microalga),

Phaffia rhodozyma (a yeast), and certain bacteria (*Paracoccus* and *Agrobacterium* species) have been identified as viable sources for industrial-scale astaxanthin production.

The demand for natural astaxanthin is increasing due to consumer preference for natural colorants and health supplements over synthetic alternatives. Microbial production offers a controlled, environmentally friendly, and efficient means of generating high-purity astaxanthin. This review explores the significance of microbial astaxanthin, its biotechnological production methods, and its various applications in the food and feed industries.

Microbial Sources of Astaxanthin

Several microorganisms are capable of producing astaxanthin, with the most notable being:

- Microalgae (*Haematococcus pluvialis*): The richest natural source of AXT, widely used in commercial production.
- Yeast (*Phaffia rhodozyma*): A well-studied fungal source with potential for industrial fermentation.
- Bacteria (*Paracoccus* spp. and *Agrobacterium* spp.): Emerging sources with promising biosynthetic pathways.

Microbial fermentation provides a scalable and sustainable approach to AXT production, overcoming limitations associated with traditional sources (Panis et al., 2016).

Biosynthesis and Production Methods

The biosynthesis of astaxanthin in microorganisms involves a series of enzymatic reactions starting from isoprenoid precursors. Key steps include:

1. Carotenoid Biosynthesis: Conversion of geranylgeranyl pyrophosphate (GGPP) into phytoene, followed by desaturation and cyclization into β -carotene.
2. Oxidation of β -Carotene: The enzyme β -carotene ketolase converts β -carotene into astaxanthin by introducing keto groups at specific positions.
3. Enhancing Production Efficiency: Genetic engineering and metabolic pathway optimization improve yield and cost-effectiveness.

Commercial-scale production of microbial astaxanthin typically involves:

- Phototrophic Cultivation: Used for *Haematococcus pluvialis* under stress conditions to maximize AXT accumulation.
- Heterotrophic Fermentation: Employed for *Phaffia rhodozyma* and bacterial strains to facilitate large-scale production.

- Bioprocess Engineering: Strategies such as optimizing media composition, controlling environmental factors, and utilizing recombinant technology.

Applications in Food Industry

In human nutrition, AXT is incorporated into various food products due to its antioxidant, anti-inflammatory, and immune-boosting properties. Key applications include:

- Functional Foods & Beverages: Added to juices, dairy products, and dietary supplements for its health benefits.
- Nutraceuticals: Used in soft gels and capsules to support eye health, skin protection, and cardiovascular health.
- Food Coloring: Provides a natural red-orange hue to processed foods without synthetic additives.

Applications in Animal Feed

AXT plays a crucial role in aquaculture and livestock nutrition, improving pigmentation and overall health. Key applications include:

- Aquaculture: Enhances the coloration and health of salmon, trout, shrimp, and other marine species.
- Poultry Feed: Improves egg yolk pigmentation and supports immune function in chickens.
- Livestock & Pet Nutrition: Acts as an antioxidant and enhances the overall health of farm animals and pets.

Health Benefits and Safety Considerations

Astaxanthin is recognized for its strong antioxidant activity, contributing to various health benefits:

- Anti-inflammatory Effects: Reduces oxidative stress and inflammation in both humans and animals.
- Cardiovascular Support: Lowers the risk of heart diseases by improving lipid metabolism.
- Neuroprotective Properties: Protects against neurodegenerative disorders like Alzheimer's disease.

Despite its advantages, microbial astaxanthin production faces challenges such as high production costs and optimization of yield. Future research should focus on genetic engineering,

bioprocess optimization, and alternative microbial strains to enhance productivity and cost-effectiveness.

- Strain Improvement: Genetic modifications to enhance AXT biosynthesis.
- Fermentation Optimization: Developing cost-effective and high-yield processes.
- Industrial Applications Expansion: Exploring new uses in cosmetics, pharmaceuticals, and bio-based materials.

Conclusion

Microbial astaxanthin presents a sustainable and effective alternative to synthetic and marine-derived sources, with extensive applications in food and animal feed. Its numerous health benefits, including strong antioxidant and anti-inflammatory properties, make it an essential ingredient in human nutrition and animal diets. While challenges remain in optimizing production costs and yield, advances in biotechnology, fermentation technology, and metabolic engineering hold promise for making microbial astaxanthin more commercially viable. As demand for natural carotenoids increases, microbial biotechnology will play a vital role in enhancing AXT production and its utilization in diverse industries.

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BROWN MANURING: A SUSTAINABLE APPROACH TO NUTRIENT MANAGEMENT

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Abstract

Indian agriculture is undergoing a transformation, with increasing focus on improving nutrient resource management. Efficient nutrient management is crucial for achieving sustainable crop yields. To meet the nutrient demands of crops and ensure yield stability, it is essential to integrate all available nutrient sources. While chemical fertilizers contribute significantly, organic manures also hold an important place in this strategy. However, due to their bulky nature and low nutrient concentration, complete substitution with organic manures is often impractical. Among the various alternatives, brown manuring emerges as a promising and practical option for integrated nutrient management.

Keywords: Brown manuring, Integrated nutrient management, Organic manures, Chemical fertilizers, Sustainable agriculture

Introduction

Modern agriculture faces the dual challenge of increasing cultivation expenses and the rising cost of essential inputs, particularly fertilizers. Although synthetic fertilizers have played a vital role in enhancing crop productivity and ensuring food security, their excessive and long-

term use has resulted in nutrient imbalances, deterioration of soil health, and reduced nutrient-use efficiency. To overcome these drawbacks, the practice of Integrated Nutrient Management (INM) which involves combining organic materials such as compost, farmyard manure, and green manures with chemical fertilizers is encouraged. This approach not only fulfills crop nutrient demands but also enhances soil structure, promotes microbial activity, and boosts moisture retention capacity. India, being an agrarian nation, generates substantial agricultural and urban bio-waste that has the potential to be transformed into nutrient-rich compost. However, a large portion of this resource goes unused due to limited processing facilities, lack of awareness, and the high cost of transporting bulky organic materials. Strengthening scientific composting practices, streamlining distribution channels, and promoting INM can help reduce dependence on chemical fertilizers, rejuvenate soil fertility, and support environmentally sustainable and efficient agricultural systems.

BROWN MANURING

Brown manuring is an innovative agronomic practice that combines the benefits of green manuring with weed suppression and soil improvement, while reducing tillage operations. The concept of brown manuring was first introduced in the Lockhart district of New South Wales, Australia, in 1996. The pioneer of this practice was Goodens, who adopted it as a strategic measure to control herbicide-resistant ryegrass populations in winter crops. In the Australian context, brown manuring involved the use of cover crops grown with the specific objective of terminating them before they set seed, thus preventing weed proliferation. These cover crops were typically terminated by applying herbicides instead of being physically incorporated into the soil. The practice served multiple purposes: it allowed rotation of herbicide modes of action to delay resistance development, maintained soil cover to prevent erosion, reduced weed seed banks, contributed nitrogen through biological nitrogen fixation by legumes, and improved soil structure and water-holding capacity, thereby offering significant agronomic advantages. Brown manuring can be defined as the cultivation of green manuring crops such as dhaincha (*Sesbania aculeata*), sesbania, sunhemp (*Crotalaria juncea*), and similar species either as intercrops or mixed crops with the main crop, followed by the application of post-emergence herbicides to desiccate them before flowering. This distinguishes brown manuring from conventional green manuring, where crops are physically incorporated into the soil through ploughing. Brown manuring represents a *no-till* version of green manuring, where herbicides are used to kill the

green manure crop in situ, and the residues are left undisturbed on the soil surface. The primary aim of brown manuring is to produce a high biomass of leguminous green manure crops with minimal input of fertilizers and herbicides, ensuring maximum dry matter accumulation before major weeds establish viable seed banks. Once terminated with herbicide, the crop residues remain in the field, decomposing slowly and enriching the soil with organic matter and nutrients, particularly nitrogen. At the same time, the residue acts as a mulch layer, suppressing weed growth through shading and allelopathic effects. In this technique, the application of post-emergence herbicides on the foliage of green manure crops leads to the breakdown of chlorophyll, resulting in a visible brown discoloration of leaves, hence the term *brown manuring*. The dead plant material forms a protective mat on the soil surface, enhancing moisture retention, reducing soil temperature fluctuations, and **improving** microbial activity during decomposition. Brown manuring is particularly effective in cropping systems where minimal soil disturbance is preferred. It offers a sustainable and eco-friendly approach to weed management, nutrient recycling, and overall soil health improvement, especially in conservation agriculture and rice-based cropping systems.

BENEFITS OF BROWN MANURING OVER GREEN MANURING

Conventional green manuring involves growing specific manure crops before sowing the main crop and incorporating them into the soil through ploughing. While beneficial for improving soil fertility and structure, this method **requires** several field operations, including sowing, incorporation, and decomposition, which can result in significant soil disturbance, moisture loss, and increased labor, fuel, and irrigation expenses. In contrast, brown manuring presents a more efficient and cost-effective alternative. Rather than ploughing the manure crop into the soil, brown manuring relies on post-emergence herbicides to desiccate the crop, eliminating the need for tillage. This approach minimizes soil disruption, conserves moisture, and reduces input costs. Additionally, brown manuring is compatible with standing crops, as green manure species such as Sesbania or sunhemp are intercropped or mixed with the primary crop. This allows farmers to utilize the same land and growing period for both crops, enhancing land-use efficiency. The decomposing plant residues offer continuous ground cover, improve nitrogen availability through biological fixation, and suppress weeds by shading. Consequently, brown manuring integrates well with existing cropping systems and proves especially

advantageous in rainfed or low-resource farming environments, offering a sustainable and practical alternative to traditional green manuring.

COMPARISON: GREEN MANURING VS. BROWN MANURING

Aspect	Green Manuring	Brown Manuring
Definition	Involves the incorporation of a manure crop into the soil through tillage, usually before flowering or seed set.	A no-till method where the manure crop and weeds are killed using post-emergence herbicides.
Soil Disturbance	Requires tillage, leading to soil disturbance.	No tillage is involved, preserving soil structure.
Soil Erosion Risk	Increases the risk of soil surface erosion, especially in light-textured soils.	Residues are left standing, helping to protect the soil surface and reduce erosion.
Moisture Requirement	Requires adequate soil moisture for crop incorporation and microbial decomposition.	Helps conserve soil moisture as there is no disturbance and the plant cover reduces evaporation.
Decomposition Process	Relies on microbial activity for decomposition of incorporated biomass.	Relies on chemical desiccation; microbial decomposition occurs gradually in situ without incorporation.
Timing of Cultivation	Manure crop is grown before the main crop, needing a separate cultivation window.	Manure crop can be intercropped or mixed with the standing main crop, saving time and space.
Cost & Labor	High labor, fuel, and irrigation costs due to multiple field operations.	Cost-effective due to reduced field operations and labor requirements.
Weed Management	Less effective in suppressing weeds.	Provides effective weed suppression through shading and herbicidal action.

CROPS USED FOR BROWN MANURING

Brown manuring can be performed using both non-leguminous and leguminous crops. The choice of crop depends on the specific agronomic goals, such as organic matter addition, nitrogen fixation, weed suppression, and soil moisture conservation.

Type of Crop	Description	Examples
Non-Leguminous Crops	Grown mainly for adding organic matter to the soil. They do not fix atmospheric nitrogen but help improve soil structure, enhance microbial activity, and conserve moisture. Less commonly used for brown manuring due to limited nitrogen-fixing ability.	Niger (<i>Guizotia abyssinica</i>), Wild Indigo (<i>Tephrosia</i> spp.)
Leguminous Crops	Preferred for brown manuring as they contribute organic matter and enrich soil with nitrogen through symbiosis with <i>Rhizobium</i> in root nodules. Highly beneficial for nutrient-depleted soils and long-term soil fertility.	Sunnhemp (<i>Crotalaria juncea</i>), Dhaincha (<i>Sesbania aculeata</i>), Mung Bean (<i>Vigna radiata</i>), Cowpea (<i>Vigna unguiculata</i>), Lentil (<i>Lens culinaris</i>)

QUALITIES OF AN IDEAL BROWN MANURE CROP

To be effective in a brown manuring system, the selected crop should meet specific agronomic and ecological criteria. These qualities ensure that the crop supports weed management, nutrient cycling, and soil health without negatively affecting the main crop.

- ✓ Seeds should be readily available in the market and economically affordable for farmers.
- ✓ The crop should be easy to grow and exhibit vigorous, healthy growth.

- ✓ It should be capable of producing a large amount of dry matter within a short growth period.
- ✓ The crop should be competitive enough to suppress the growth of target weed species.
- ✓ It should provide dense ground coverage to minimize wind erosion and help conserve soil moisture.
- ✓ The crop must not compete with the main crop for essential resources like light, water, or nutrients.

ADVANTAGES OF BROWN MANURING

- ✓ Brown manuring enhances soil organic carbon levels, thereby contributing to biological nitrogen fixation (BNF), which supplies nitrogen to companion crops. This natural nitrogen input can reduce the need for synthetic nitrogen fertilizers by up to 25%.
- ✓ It helps increase crop yield, thereby improving economic returns for farmers and enhancing farm profitability.
- ✓ The practice positively influences soil health indicators, including increased organic matter content and a rise in beneficial earthworm populations.
- ✓ Brown manuring effectively suppresses early-stage weed growth due to the rapid biomass accumulation and competitive nature of the manure crop, which shades out weeds.
- ✓ It significantly improves soil physico-chemical properties such as soil structure, organic carbon content, bulk density, and pH, contributing to long-term soil fertility.
- ✓ The integration of herbicide application with brown manuring has been shown to enhance protein content in grains and overall protein yield, outperforming conventional crop management practices.

Conclusion

In light of the escalating costs of chemical fertilizers and growing concerns about sustainable agriculture, brown manuring emerges as an effective, low-cost strategy for improving crop productivity and farm profitability. It not only enhances nutrient availability and crop yields but also contributes to the restoration of soil quality—a pressing need in modern agriculture. With its proven benefits in terms of soil health, weed suppression, and reduced dependency on external inputs, brown manuring offers a sustainable and eco-friendly alternative to intensive



chemical use. Therefore, it is essential that extension agencies and agricultural practitioners actively promote the adoption of brown manuring practices to help farmers harness its full potential for improved livelihoods and environmental sustainability.

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FROM OCEAN TO WELLNESS: BIOACTIVE FISH PEPTIDES FOR FOOD AND HEALTH

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Abstract

Fish are widely acknowledged as a sought-after food source due to their rich nutritional profile, including proteins, peptides, lipids, omega-3 fatty acids, vitamins, and minerals. Proteins and peptides from fish are crucial in developing functional foods due to their nutritional and functional characteristics. Fish proteins (FPNs) provide essential amino acids and bioactive peptides, making them ideal for sustainable specialty food production. The functional attributes of FPNs and peptides enhance fish-based products' nutritional and sensory qualities. This technical article explores nutraceutical properties and eco-friendly extraction methods like enzyme-based hydrolysis and microbial fermentation, assessing their effectiveness in producing bioactive peptides for food systems. It examines the health benefits of fish peptides (FPs), including antioxidant, antihypertensive, antidiabetic, and immunomodulatory effects in specialty foods. The technical article reviews fish-derived proteins and peptides as food preservatives, emulsifiers, and antioxidants, providing insights into creating nutraceuticals and functional foods that meet consumer demand for sustainable and health-focused dietary choices.

Keywords: Fish proteins; Bioactive peptides; Nutraceutical properties; Pharmaceutical potential; Sustainable food

Introduction

Fish proteins and peptides are vital for human nutrition due to their excellent amino acid profiles, bioavailability, and biological functions. Derived from aquatic organisms, they hold promise as nutraceuticals and functional food ingredients. These compounds are rich in essential amino acids like lysine, methionine, and tryptophan, aligning well with human dietary needs. Fish peptides: short amino acid sequences typically produced through enzymatic hydrolysis exhibit bioactive properties such as antioxidant, antihypertensive, antimicrobial, and immunomodulatory effects (Perez et al., 2012). Sourced from both muscle tissue and by-products like skin and bones, fish peptides also support sustainability when derived from processing waste. Extraction methods like enzymatic hydrolysis and emerging technologies such as ultrasound-assisted extraction improve efficiency and peptide functionality.

Fish peptides act as natural antioxidants, preserving food and combating oxidative stress, which contributes to chronic diseases. Their antihypertensive effects stem from ACE inhibition, while antimicrobial peptides disrupt harmful bacteria. Immunomodulatory properties further enhance their health potential. These versatile peptides are used in food, pharmaceuticals, and cosmetics, where fish collagen peptides promote skin hydration and reduce wrinkles. Sustainable production reduces environmental impact, though challenges remain, including quality variation, regulatory concerns, and the need for standardization and clinical validation (Je et al., 2005).

Nutritional Composition

Fish muscle proteins are primarily composed of myofibrillar proteins (70–80%), sarcoplasmic proteins (25–30%), and a small portion of stroma proteins (around 3%). Sarcoplasmic proteins (SPs) are more abundant in pelagic fish like sardines and contain enzymes and heme proteins that improve the stability of meat products. Myofibrillar proteins (MPs), found in high amounts in flatfish, play a key role in coagulation, gelation, and moisture retention through components like actin and myosin. Stroma proteins, rich in elastin and collagen, are less prevalent but still significant. SPs, particularly in dark meat, also contribute to the biodegradability and quality of food products. Fish is a highly nutritious food source, rich in polyunsaturated fatty acids and high-quality proteins. Fish proteins break down into peptides with various health-promoting effects, including antioxidant, anti-inflammatory, and cardiovascular benefits. Peptide fractions have demonstrated the ability to neutralize free radicals, which contribute to diseases such as Alzheimer's, cardiovascular disease, and diabetes.

Marine collagen peptides have shown neuroprotective effects by reducing acetylcholinesterase activity in the brain, potentially aiding in age-related cognitive disorders (Xu et al., 2015). Additionally, fish oils have been linked to cardiovascular health by promoting antioxidant enzyme activity and mitigating atherosclerotic lesions (Wang et al., 2004).

Extraction

Functional peptides (FPs) have garnered interest due to their bioactive properties, offering health advantages including antioxidant, antimicrobial, and antihypertensive effects. These peptides are derived from fish by-products like skin, bones, scales, and viscera, adding value to waste and promoting sustainable practices. This analysis investigated extraction methods for FP generation, including protein extraction, hydrolysis, and purification methods. The seafood sector produces significant waste, representing up to 50% of fish biomass. These secondary products contain proteins, collagen, and bioactive substances that can become valuable components like FPs. FPs are brief AA sequences obtained from proteins, known for their biofunctional properties and health benefits (Shahidi & Zhong, 2008). The extraction procedure is vital for peptide yield, quality, and bioactivity. Efficient extraction techniques facilitate valuable peptide retrieval while reducing deterioration and ensuring scalability. This assessment details the techniques used in FP production, their concepts, and related advantages. Protein extraction served as the basis for FP production.

Bioactivity of FPNs and Peptides

Fish protein nutrients (FPNs) exhibit several key bioactivities, including antioxidant, anti-inflammatory, anticancer, and antihypertensive effects. Antioxidant activity is particularly important for countering oxidative stress caused by free radicals such as alkyl, hydroxyl, and peroxide species. An imbalance between these radicals and the body's antioxidant defenses can lead to cancer, inflammation, and skin damage. Fish-derived antioxidant peptides, typically within a molecular weight range of 0.5–1.5 kDa, help neutralize these radicals and support cellular protection. Their effectiveness depends on peptide composition and the presence of free amino acids. Antihypertensive activity is another major benefit, as fish protein hydrolysates can inhibit angiotensin-converting enzyme (ACE), which regulates blood pressure by converting angiotensin I to the vasoconstrictor angiotensin II. This ACE inhibition supports blood pressure management and cardiovascular health. Hydrolysates from various marine sources have shown strong ACE-inhibitory effects in animal studies (Balti et al., 2015). Anticancer activity has also

been noted, with certain fish-derived peptides demonstrating the potential to inhibit tumor growth. These effects are thought to be linked to the amino acid composition, particularly glycine, proline, and alanine, which may influence peptide interactions with cancer cells. Some studies suggest that fish-derived antioxidants can support cancer treatment by reducing oxidative damage and enhancing immune function (Leng et al., 2005).

Nutraceutical Properties of Peptides

Fish is a highly nutritious food source, yet its processing generates significant waste, including scales, bones, and skin. Globally, an estimated 7.2 to 12 million tonnes of fish waste are discarded each year. While often used to produce lower-value products like fishmeal and feed, this waste holds untapped potential. Fish scales, in particular, contain valuable compounds such as collagen, chitin, and hydroxyapatite, which can be transformed into functional peptides with health-promoting properties (Wang et al., 2021). These marine-derived peptides have demonstrated a range of bioactivities, including antioxidant, antihypertensive, antibacterial, anticancer, and immunomodulatory effects. Currently research focuses on utilizing these peptides to support nutrition, food development, and medical applications. By regulating oxidative stress and enhancing immune responses, they may help prevent malnutrition and improve key health markers such as haemoglobin, serum protein, and IGF-1 levels. In populations affected by stunting, fish-derived peptides show potential in supporting healthy growth. Fish-scale collagen also offers advantages over mammalian sources due to its biocompatibility, mechanical strength, and lower risk of zoonotic disease transmission, making it suitable for food, pharmaceutical, and cosmetic applications (Li et al., 2019).

Cosmeceutical Properties of Peptides

Marine fish contain bioactive substances like proteins and peptides, attracting interest from pharmaceutical and cosmeceutical industries for their antibacterial, antiaging, and antioxidant properties. Proteins and peptides from marine fish, obtained through enzymatic hydrolysis of processing waste, have grown important in cosmeceutical development due to their antioxidant properties and tissue regeneration ability. Collagen from marine fish is valuable for skin repair, while fish-derived peptides provide antioxidant and antibacterial benefits. This technical article reviews recent developments in isolating and using marine fish proteins and peptides as cosmeceutical components. Marine fish proteins comprise small peptides with complete protein sequences. Bioactive peptides are extracted from marine organisms through

enzymatic hydrolysis. Fish species like tuna, salmon, and eels contain histidine-containing dipeptides - carnosine and anserine (Wu et al., 2003). These peptides serve medicinal and cosmetic purposes (Cheung et al., 2015). Bioactive peptides contain three-twenty AA residues and demonstrate antibacterial, antioxidant properties while boosting immunity (Halim et al. 2016). Chymotrypsin and alkalis are common proteinases for FPN hydrolysis.

The body relies on antioxidants to defend against oxidative harm. Reactive oxygen species (ROS) cause oxidative stress, and an imbalance between free radicals and antioxidants can lead to health issues like skin damage, inflammation, cancer, and neurological disorders (Birben et al. 2012). Free radicals damage proteins, lipids, DNA, and cellular membranes, contributing to skin aging (Rinnerthaler et al., 2015). The body uses antioxidant enzymes and molecules, including vitamin C, glutathione, and ubiquinone, to counteract free radicals (Rinnerthaler et al., 2015). Methods to evaluate fish-derived peptides' antioxidant properties include DPPH and ABTS radical scavenging assays, and tests for hydroxyl radical scavenging and ion chelation (Gajanan et al., 2016). Antimicrobial peptides interact with microbial pathogen membranes due to their cationic characteristics (Bardan et al., 2004). Researchers are developing cosmeceutical products from sea creatures, as marine fish peptides show antibacterial qualities (Kangsanant et al. 2015).

Conclusion

Proteins and peptides from fish have significant effects on human health and nutrition. Their bioactive properties and sustainability make them ideal for functional foods, nutraceuticals, and cosmeceuticals. Studies revealing their bioactivity suggest growing potential for innovation and application. Fish peptide extraction involves protein extraction, hydrolysis, and refining, with traditional and emerging technologies offering opportunities for improved efficiency. Ongoing research will enhance the market potential of FPs and support sustainable seafood development. FPs and proteins show promise in the food and nutraceutical sectors due to their health benefits. Research on production methods, biological processes, and safety will expand their applications, supporting sustainable fish processing and functional food needs. Further studies are needed to identify additional bioactive properties like neuroprotective and immunomodulatory effects. Scaling up production processes, ensuring nutrient compatibility, maintaining gastrointestinal stability, and guaranteeing safety remain essential challenges.



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GREEN HORIZONS: THE ROLE OF AGRICULTURE IN SPACE EXPLORATION

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Abstract

As humanity progresses toward establishing settlements on extraterrestrial bodies such as Mars and the Moon, sustainable agricultural farming becomes a critical component for survival. Future space missions depend on self-reliant systems capable of producing food, recycling resources, and maintaining human health. This article explores how agricultural innovations, including controlled environment agriculture (CEA), hydroponics, aeroponics, and bio-regenerative life support systems (BLSS), can support human life on aeroplanets. It also highlights India's potential contributions to this emerging interdisciplinary field in collaboration with space research and agricultural institutions.

Keywords: Space Agriculture, Controlled Environment Agriculture, Extraterrestrial Farming, Mars Colonization, Bio-regenerative Life Support, Hydroponics, ISRO, NASA, Sustainability

Introduction

With space agencies planning permanent lunar outposts and manned Mars missions, establishing reliable food production systems is no longer a science fiction concept. Human survival in space hinges on localized food production due to high costs and risks associated with resupply missions. However, extreme environmental factors—such as lack of atmosphere, extreme temperature variations, microgravity, and radiation—render traditional Earth farming methods impractical. Controlled Environment Agriculture (CEA) technologies provide a feasible alternative for food security in space by optimizing growth parameters independent of natural weather. NASA, ESA, Roscosmos, and private companies like SpaceX and Blue Origin are investing heavily in space farming research, and ISRO too has begun laying groundwork through

interdisciplinary collaborations.

2. Methodology and Technological Approaches

2.1 Controlled Environment Agriculture (CEA)

CEA systems rely on **fully enclosed and monitored environments** with artificial light (LEDs tuned to specific photosynthetic spectra), precise CO₂ and humidity control, and automated nutrient delivery. Innovations include:

- ✓ **AI-integrated climate control** systems (e.g., Lufa Farms, Canada).
- ✓ **Vertical farming stacks** for compact environments, using robotics for seeding and harvesting.
- ✓ Modular **plant growth units**, e.g., NASA's **Advanced Plant Habitat (APH)**, and the **EDEN ISS** project in Antarctica as a **Martian farming** analogue.



2.2 Hydroponics and Aeroponics

Hydroponics uses nutrient-rich water, while aeroponics delivers misted nutrients directly to plant roots. These systems are:

- ✓ Lightweight, efficient, and **ideal for low-gravity environments**.
- ✓ Able to support a wide range of crops including leafy greens, microgreens, and root vegetables.
- ✓ Advanced systems like **NASA Veggie**, **Kennedy Space Center's Veggie Lab**, and **Orbital Farms** use closed-loop hydroponics with real-time remote monitoring.

2.3 Bio-regenerative Life Support Systems (BLSS)

BLSSs emulate Earth's biosphere by recycling air, water, and organic waste through biological processes. Recent developments:

- ✓ **MELiSSA (ESA)** uses **microalgae and higher plants** to regenerate oxygen and purify water.
- ✓ **Closed-loop nutrient cycling** integrating human waste composting into plant growth media.
- ✓ Use of **engineered microbial consortia** to break down waste and enhance nutrient availability.

2.4 Radiation Shielding and Genetic Modification

Plants on Mars or the Moon face high radiation levels.

Approaches include:

- ✓ **CRISPR-Cas9 gene editing** for developing **radiation-resistant, fast-growing crops** (e.g., lettuce, wheat).
- ✓ **Synthetic biology** to engineer photosynthetic organisms for multipurpose applications (nutrition, pharmaceuticals).
- ✓ Using **regolith-based shielding domes** and **underground greenhouses** to protect crops from solar and cosmic radiation.

2.5 Indian Prospective and Contributions

India's agricultural innovation potential combined with its space capabilities offers strong prospects:

- ✓ ISRO can collaborate with **ICAR and SAUs** to develop **space-specific crop varieties**, waste recycling methods, and lightweight farming modules.
- ✓ Development of **low-resource, high-output technologies** suited for confined habitats.
- ✓ Indigenous **solar-powered hydroponic kits** and **smart irrigation systems** are highly adaptable for extraterrestrial settings.

3. Results and Observations

3.1 Global Developments

- ✓ **NASA's Veggie and Advanced Plant Habitat** have grown lettuce, radishes, mustard greens, and zinnias aboard the ISS, helping study plant growth under microgravity.

- ✓ **ESA's MELiSSA** ecosystem supports oxygen, food, and water regeneration.
- ✓ **China's Chang'e-4** mission attempted a sealed biosphere with potato seeds and silkworms on the Moon's far side.
- ✓ The **EDEN ISS Mobile Greenhouse** in Antarctica successfully grew tomatoes, cucumbers, and greens in sub-zero conditions.

3.2 Agricultural Benefits for Space Missions

- ✓ **Food Security:** Fresh food production reduces dependency on Earth, enhances nutrition, and decreases payload cost.
- ✓ **Psychological Health:** Greenery and plant care have been shown to reduce astronaut stress.
- ✓ **Atmospheric Recycling:** Plants absorb CO₂ and release oxygen, forming a natural air purification loop.
- ✓ **Water Purification:** Root systems and plant-based filters aid in **graywater reuse**.
- ✓ **Waste Management:** Compostable biomass can be reintegrated into the system, supporting circular resource use.

3.3 India's Emerging Role

- ✓ Agricultural Engineering Colleges and institutions like AAU, IARI, and IITs can work with ISRO and DRDO on **CEA module prototyping, genetic crop design, and low-energy automation**.
- ✓ Joint ventures with private firms for **space farming test beds** can position India in the global race for space sustainability.

Agricultural Engineering colleges and institutions like **Anand Agricultural University (AAU)**, **Indian Agricultural Research Institute (IARI)**, and **Indian Institutes of Technology (IITs)** can play a crucial role in advancing space agriculture by collaborating with space agencies like **ISRO** (Indian Space Research Organisation) and **DRDO** (Defence Research and Development Organisation). The combination of agricultural engineering expertise with space technology can lead to the development of sustainable, efficient, and resilient systems for farming in extraterrestrial environments.

Conclusion

Agriculture is not merely a source of food but a vital system for sustaining human presence on aeroplanets. Advances in hydroponics, aeroponics, and CEA offer a roadmap for



closed-loop farming in space. The integration of biotechnology, robotics, and AI will further enhance the resilience of space farming systems. India, with its deep-rooted agricultural expertise and growing space ambitions, stands at the cusp of contributing significantly to extraterrestrial food systems. Interdisciplinary collaborations will be key to transforming futuristic concepts into viable, scalable technologies for the cosmos.

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INNOVATIVE AGRICULTURAL PRACTICES: ADVANCING SUSTAINABLE FARMING FOR THE FUTURE

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Abstract

The global demand for food, fiber, and fuel is increasing due to rapid population growth and climate change. Traditional farming practices alone are no longer sufficient to meet these demands sustainably. Innovative agricultural practices that leverage modern technologies, ecological approaches, and resource efficiency are revolutionizing the way we cultivate crops and rear livestock. This article explores key innovations in agriculture—such as precision farming, vertical farming, biotechnology, and integrated pest management—and their role in enhancing productivity, reducing environmental impact, and ensuring food security.

1. Introduction

Agriculture is at the heart of human civilization and economic development. However, unsustainable practices, soil degradation, water scarcity, and climate variability pose significant threats to agricultural productivity. In response, innovative agricultural practices are being adopted globally to improve yield, conserve resources, and adapt to environmental changes.

2. Precision Agriculture

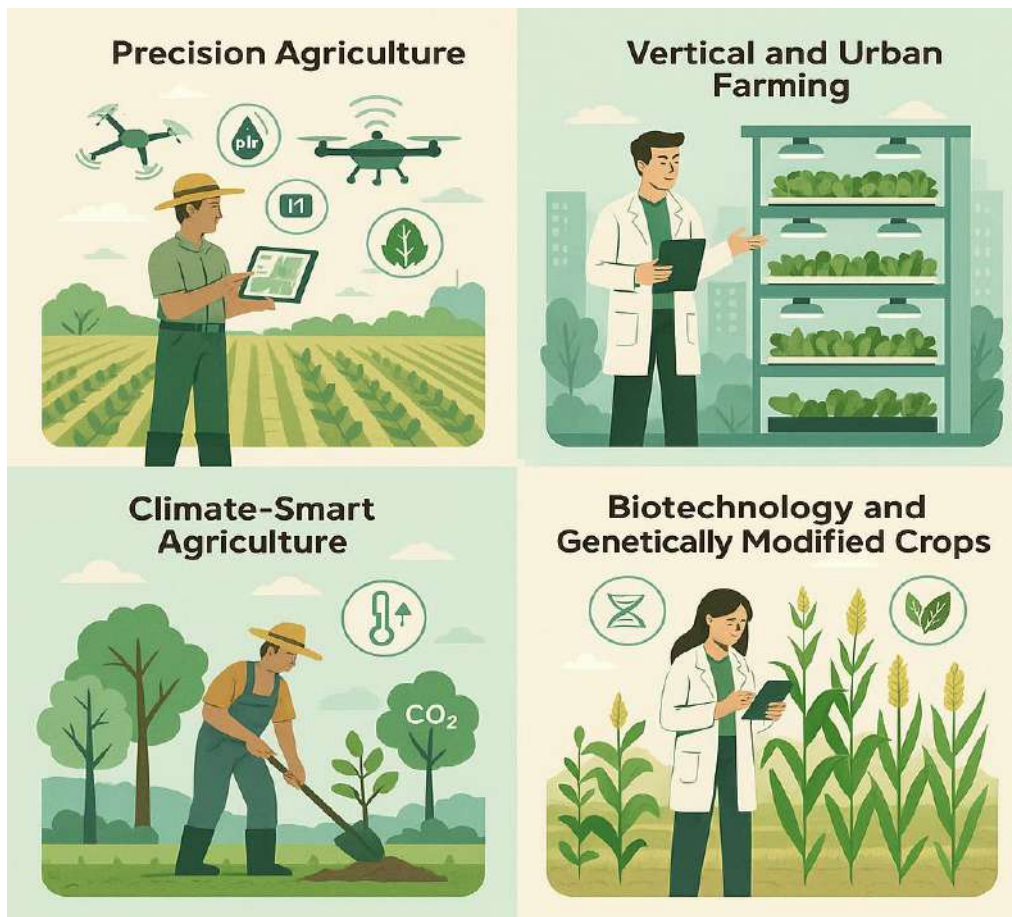
Precision agriculture (PA) involves the use of GPS, sensors, drones, and data analytics to monitor field variability and manage crops at a micro level. PA allows farmers to apply fertilizers, pesticides, and water more efficiently, reducing waste and environmental impact.

Example: Variable Rate Technology (VRT) allows differential application of inputs based on real-time data, enhancing resource use efficiency (Zhang et al., 2002).

3. Vertical and Urban Farming

Vertical farming utilizes stacked layers of crops grown in controlled environments. It reduces land use and can be practiced in urban areas, minimizing food miles and offering year-round production.

Example: LED lighting and hydroponics in vertical farms can increase yield per unit area by up to 10 times compared to traditional farming (Despommier, 2010).



4. Climate-Smart Agriculture (CSA)

CSA integrates sustainable farming practices that improve productivity, resilience, and carbon sequestration. It includes crop diversification, conservation tillage, and agroforestry.

Example: Agroforestry systems improve soil fertility and provide shade, which can help reduce crop stress during heatwaves (FAO, 2013).

5. Biotechnology and Genetically Modified Crops

Biotechnology allows for the development of crops with improved traits such as drought tolerance, pest resistance, and enhanced nutrition.



Example: Bt cotton and Bt corn have significantly reduced the use of chemical pesticides in countries like India and the USA (Qaim & Zilberman, 2003).

6. Integrated Pest Management (IPM)

IPM combines biological, cultural, physical, and chemical tools to manage pests in an ecologically and economically sound manner.

Example: Use of pheromone traps and natural predators has reduced pest incidence in rice and cotton fields in Asia (Kogan, 1998).

7. Use of Renewable Energy in Agriculture

Solar-powered irrigation systems and biogas digesters are increasingly being used in farms, reducing dependency on fossil fuels and lowering greenhouse gas emissions.

Example: Solar pumps have improved irrigation access for smallholder farmers in India and sub-Saharan Africa, boosting productivity (Burney et al., 2010).

8. Digital Agriculture and AI

Artificial Intelligence (AI), machine learning, and mobile apps are enabling real-time decision-making and remote farm management.

Example: AI-based tools can predict pest outbreaks or recommend optimal planting schedules, enhancing productivity and risk management (Kamilaris et al., 2018).

9. Conclusion

Innovative agricultural practices are transforming the way we produce food. By integrating technology, ecological principles, and sustainable resource management, these innovations offer viable solutions to the challenges of modern agriculture. Future policies and investments should support the adoption of these practices to ensure global food security and environmental sustainability.

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MANGO: AN IMPORTANT CROP

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Introduction

Mango is known as king of fruit. Aam, the vernacular name of mango, means common. It is certainly the fruit of millions of common men of our country. Mango is one of the ancient fruit of India. It is very popular fruit than others. It is an outstanding source of vitamin A. Akabar the great was planted the famous Lakhbag, an orchard of 10000 mango tree, near Darbhanga. Mango is now cultivated in several countries of the tropical and subtropical world, where it was introduced by Muslim missionaries.

Other name: King of fruits, National fruit of India, Bathroom Fruit**Botanical Name:** *Mangifera indica* L.**Family:** Anacardiaceae**Origin:** Indo-Burma**Type of fruit:** Drupe**Edible portion:** Mesocarp**Chromosome Number:** $2n=40$ ($X=10$), Amphidiploid**Uses:**

- Young and unripe fruits, because of their acidic taste are utilized for culinary purposes as well as for preparing pickles, chutneys and amchoor.
- Ripe fruits are utilized in preparing squash, nectar, jam, cereal flakes, custard powder and baby food, mango leather and toffee. Besides, fruits of some cultivars like Alphonso and Deshehari are sliced and canned for catering to the needs of consumers during the off-season.

Composition (Raw mango): Moisture 90%, Vitamin A 150 a.i., Fat: 0.1%, Carbohydrates 8.8%, Protein: 0.7%, Vitamin C: 3 mg/100 g of edible portion

History: The great emperor Akbar (1556-1605) was established *Lakh Bagh* (a mango orchard having 100000 plants) in Darbhanga (Bihar).

Improved Cultivars: The popular commercial cultivars of different region in India are –

- Northern region: Dashehari, Langra, Chausa and Bombay Green.
- Eastern region: Himsagar, Fazli, Krishnabhog and Gulabkhas.
- Western region: Alphonso, Pairi, Kesar, Rajapuri.
- Southern region: Bangalora, Neelumn, Swarnarekha, Banganpalli, Mulgoa.

Hybrid Mango Cultivars: IARI – Amrapali, Mallika.

IIHR – Arka Aruna, Arka Anmol, Arka Neel Kiran, Arka Puneet.

Categorisation of mango varieties: Grouping of mango varieties on their uses, area, climate, bearing habit, taste, embryonic nature etc.

- **Polyembryonic varieties:** Olour, Goa, Salem, Chandra karan, and Bellary, Bappakai, Kurukkan, Mazagaou, Nileshtar Dwarf and Mulepalium (found in India).
- **Sucking type varieties:** Raspunia, Mithwa Ghazipur, Mithwa Sundershar, Hardil Aziz and Lucknow Safeda for U.P., Chinna Rosam, Cherukurasam and Pedda Rasam for Andhra Pradesh, Rajapuri for Gujarat.
- **For export:** Alphonso, Kesar, Gulabkhas, Sardar Pasand, Lakhan Bhog etc.
- **Season : Under Northern and Eastern India –**
 - Early** (Bombay Green, Gopalbhog, Zardalu and Rataul)
 - Mid** (Dashehari, Langra, Gulabkhas, Krishanbhog, Fajri Zafrani and Khas - ul – Khas)
 - Late** (Chausa, Fazli, Sukul etc)

Special feature of varieties such as:

Sindhu – Seedless (very thin stone) due to stenospermocarpy.

Chausa – Sweetest among all.

Niranjan – Off season flowering (Jam, Jelly).

Amarpali – Dwarf (under – H.D.P.)

Dashehari – Semi dwarf (also H.D.P.)

An ideal mango variety should have a dwarf canopy, attractive fruit colour, medium size, good

fruit quality, small stone, fibre less flesh and high keeping and transport quality. It should also be precocious and regular in bearing, highly tolerant to various diseases including malformation and pests.

There are so many new varieties have been evolved in the recent past such as:

(Through the selection):

- **Dashehari 51** – It is a superior clone, chance selection of Dashehari from C.I.S.H., Lucknow. Bears good crop every year with no “off” bearing rhythm.
- **Sunderaja** – A clone selection from Rewa, M.P.
- **Subhash** – A chance seedling selection of Zardalu from B.A.C. Sabour, Bihar.
- **Menaka** – a chance seedling selection of Gulabkhas from B.A.C Sabour, Bihar.
- **Niranjan** – Selection from private gauder of Nizam of Hyderabad.
- **Pusa Surya** – An introduced “Eldon” cultivar of U.S.A. from Brazil, released after evaluation with popular name Surya from I.A.R.I, New Delhi.

Through the Hybridization:

- **Mallika (Neelum × Dashrhari)** – Evolved at I.A.R.I., New Delhi. Tree Semi vigorous, heavy bearer, attractive large fruit (300 to 500 g), high pulp (75%) content, pulp is firm, fibreless, high TSS (24⁰Brix), Fruits ripen by 3rd week of July, good keeping quality. This hybrid has now been taken as a commercial cultivar in part of South India.
- **Amrapali (Dashehari × Neelun)** – Evolved at I.A.R.I. New Delhi, dwarf, precocious, highly regular and prolific bearer, fruit small to medium (120 to 160g), fibreless, excellent taste with high TSS (28.8⁰ Brix), late ripening (3rd week of July), suitable for high density planting, high carotenoid (16830 mg/100g pulp) content. Pulp can be used as colour additive for juice of other mango varieties.
- **Pusa Arunima (Amrapali × Sensation)** – Developed at I.A.R.I., New Delhi, Semi vigorous plant growth, regular bearer, medium fruit size (250g), thick peel, long shelf life (14 to 16 days), TSS (18.5⁰ Bricks), acidity (0.22%) Carotene content (14220mg/100g pulp), suitable for export.
- **Ambika (Amrapali × Janardhan Paysandú)** – Developed at C.I.S.H., Lucknow.
- **Gaurav (Dashehari × Totapari Hyderabad)** – from H.E.T.C., Saharanpur (U.P.)
- **Rajiv (Dashehari × Romani)** - from H.E.T.C., Saharanpur (U.P.)

- **Saurabh (Dashehari × Fazli Zafrani)** - from H.E.T.C., Saharanpur (U.P.)
- **Arka Aruna (Banganpalli × Alphonso)**
- **Arka Puneet (Alphonso × Banganpalli)**
- **Arka Neelikiran (Alphonso × Neelum)**
- **Arka Anmol (Alphonso × Janardhan Pasand)** - These are developed at I.I.H.R., Bangalore, free from Spongy tissue disorder, regular bearing habit etc.

Soil:

The Mango can grow well in all types of soil from alluvial to laterite, except black cotton soil which are considered to be poor. The most suitable pH ranges between 5.5 and 7.0. Mango is sensitive to saline conditions, producing symptoms like scorching of leaf tips and margins, leaf curling and in severe cases reduced growth causes abscission of leaves and death of trees.

Climate:

Mango is a tropical fruits. The optimum temperature for mango cultivation is 24 – 27⁰ C. Mango cannot be grown above 1000 m msl.

Propagation:

Mango plant is propagated by sexually and asexually both means. Seeded plant is not true in genotype and phenotype as compare to mother plant. The seed lose their ability to germinate within one month hence, sowing of seed immediately after separated from the fruit. Mango is commercially propagated by veneer grafting in north India and stone grafting / epicotyl grafting in humid region of coastal western India. One year old rootstock should be prepared for grafting.

Dwarfing root stock – Kalapady, Olour, Vellai Collumban, Belkhas and Parikhas.

Salt resistant root stock – Kurrukan.

Salt tolerant root stock – Moovandan and Nekkare.

Planting: With square system of planting of Amrapali at 2.5 × 2.5m and Dashehari at 3.0 × 2.5m accommodates 1600 and 1333 plants / ha. , respectively in high density orcharding in mango.

Training and Pruning:

The mango is an evergreen plant. Training is an essential practice in the initial 2-3 years for good framework. Pruning is not common practice but some varieties of mango are reported to respond well with pruning. It helps in opening up the trees and allowing to penetration of sunlight. This increases the photosynthetic efficiency of the trees and also eliminates the build-up of some insect-pests and pathogenic organism.

Crop Nutrition:

Nitrogen is the most important nutrient required for mango plant because it promotes the vegetative growth of plant. Mango plant can withstand deficiency of phosphorous, but not of potassium. The requirement of one year old plant can be met by 75 g of nitrogen, 110 g of phosphorous and 55 g of potash. 40 to 80 % of nitrogen should be in the form of FYM. These doses need to be increased by the same amount each year. A full bearing plant of Chausa variety should be given 1000 g N, 500 g P and 1000 g K as reported from Saharanpur. However, from CISH, Lucknow soil application of 400 g N, 200 g P and 400 g K per tree to ten year old Dashehari plant increased the yield. Boron and Zinc is also beneficial. Nutrient element should be given to the plant at the time of vegetative growth and fruit bud differentiation. Feeding roots of a full grown mango tree are located between 1.2 m and 2.4 m from the trunk and to the depth of 30 to 90 cm, the maximum density being within 30 cm. Hence for better utilization by the plant fertilizer application should be made in 25 cm wide and 25-30 cm deep trenches dug around the tree two m away from trunk.

Intercropping and cover – cropping :

An intercrop should be some short duration shallow – rooted vegetable crop or even a quick growing fruit plant with a short juvenile period vegetables like onion, tomato, radish, carrot, bean, cauliflower, cabbage and palak. Fruit like papaya, phalsa, guava and pineapple in tropical climate and low – chilling peach and strawberry in mild subtropical region. Cover crop like sunhemp (in light soils) or dhaincha (for heavy soils) to protect the orchard soil fertility.

Irrigation:

Irrigation must be avoided at least 2 – 3 months before flowering because it promotes vegetative growth, which will be detrimental to flowering. Irrigation must after fruit set that reduce the fruit drop and increase the fruit size.

Flowering, pollination and fruit set:

Flowering time is closely linked with time of flower bud differentiation. The flower bud differentiation in India in most cases occurs between October and December. A period of six weeks exposure at 15⁰C/10⁰C (day/night) temperature effectively induced flowering in 94 % of the trees. The flowering of mango in India takes place as early as November-December in Royala sema area of Andhra Pradesh, February to March in northern India and slightly earlier (Jan.-Feb.) in eastern parts of the country. The flowering period of mango is 2 to 3 weeks. The

mango inflorescence is panicle which bear two types of flower-male and perfect (andromonoecious). The number of flower per panicle varies between 1000 and 6000 depending upon the cultivar. The mango is a highly cross pollinated crops thus pollinating agent like common house fly, Dipterous and House fly. In this fruit crop sporophytic self-incompatibility has also reported.

Fruit drop:

The natural fruit drop in mango is rather too high, amounting to about 99 per cent at various stages of growth, more especially during the initial four weeks. Study conducted by various workers showed that in mango, in general only about 0.1% of the perfect flower developed fruits to maturity. The causes of this phenomenon are lack of pollination, low stigmatic receptivity, defective perfect flowers, poor pollen transference, self-incompatibility, lack of irrigation, unfavourable climatic conditions during fruit development period, high incidence of serious diseases like powdery mildew and anthracnose and Pests like Hopper and Mealy bug.

The fruit drop in mango can be reduced significantly by regular irrigation during the fruit development period. Timely and effective control measures against major pests and diseases can also be of great help. Fruit drop also control by the use of PGRs like NAA and 2, 4-D. Alphonso-25 ppm (2, 4-D), Langra, Chausa, Dashehari-10-20 ppm (2, 4-D)

Physiological disorders:

Mango malformation:

- First time reported by Maries (Watt, 1891)
- It is of two types i.e. vegetative and floral
- Floral malformation directly affects the productivity of mango
- The incidence is high in the varieties of Bombay Green and Chousa.
- Bhadauran and Elaichi are free from this malady.
- Malformed panicles must be pruned in the month of April and burnt.
- The causes of this disease is not only one factor so many factors are involved
- Mostly fungus is responsible
- Deblossoming of early flush of panicles at the bud burst stage when the panicles are about 1.5-2 cm long is useful

- Spraying NAA (200 ppm) or 40 ml planofix in 9 litre of water in October and deblossoming at the bud burst stage in the month of January-February

Black tip:

It is caused by the gases CO₂, SO₂ and acetylene emitted from smoke of brick kilns.

The distal end of the fruit first exhibit etiolated patches of mesocarp (Pulp portion) which turns black and hard.

Management:

- Keep the distance of orchard 1.5 Km from the brick kilns
- Keep the height of Chimneys at least 15-18 metres
- Spray of borax (0.6%) at fruit set

Spongy tissue:

Cheema and Dhani was first to observe spongy tissue in 1934. This is a serious disorder affecting mango production, particularly of Alphonso variety, which is a prized variety for export. This disorder accounts for about 30 % loss on Alphonso production annually. Other varieties prone to this problem are Swarnrekha, Vellaikolamban, Vanaraj and Fernandin. This disorder is characterized by appearance of pale yellow flesh colour, soft or spongy in nature, with or without air pockets, having off flavour. The affected tissue or pulp remain unripe due to hydrolysed starch and inactivation of amylase which in turn is due to convective heat from the ground.

Causes:

- The heat radiated from the soil surface directly heating the exposed fruits during their development and ripening stages.
- Delayed harvesting
- Soil moisture stress
- Geographical location

Control measures:

- Mulching
- Sod Culture
- Cover Cropping
- Harvesting of fruits at $\frac{3}{4}$ th size

Biennial bearing in Mango:

This is one of the most burning problem. This term is synonymous with “alternate” bearing which denotes yield variation in alternate years, i.e. a year of optimum or heavy fruiting is followed by a year of little or no fruiting. Fruiting year known as “on year” and other one is “off year”.

Causes:

There are several causes like climatological factors, age and size of shoots, C/N ratio and hormonal balance:

A. Climatological factors: Adverse climatic conditions like rain, high humidity and low temperature sometimes convert an ‘on year’ into an ‘off year’ directly or promoting the incidence of diseases like powdery mildew and anthracnose.

B. Age and size of shoots: Adverse 8-10 months maturity of shoots, which is capable of producing flower buds. This necessarily means that a certain amount of physiological maturity is prerequisite to flowering to flowering in the case of cultivars which are prone to this phenomenon.

C.C/N Ratio: Irregular bearing in mango has been caused by nutritional deficiencies especially that of nitrogen, when increase nitrogen led to vegetative growth whereas decrease favoured flowering.

D. Hormonal balance: The problem of biennial bearing in mango also appeared to be closely associated with the developing fruits on vegetative growth. Higher levels of auxin like substances and an inhibitor (Similar to ABA) and lower levels of gibberellin like substances have been vital for a floriferous shoot in mango.

Control of biennial bearing problem:

A number of remedial measures have been proposed from time to time to over come this limitation in mango production like-

- Proper upkeep and maintenance of the orchard
- Proper manuring of mango orchard (10-12 year old)
- Cultural practices (Root pruning, Application of salt, Giving incision to the bark)
- Ringing of branches in high rainfall areas
- Deblossoming
- Smudging and crop regulation through chemicals

- Pruning
- Growing of regular bearing cultivars viz. Neelum, Bangalora, Totapuri Red Small, Rumani, Mallika, Amrapali, Ratna

Jhumka or Clustering:

It is characterized by a cluster of fruitlets at the top of the panicle giving an appearance of bunchy tip called Jhumka. Dashehari is the most affected cultivar.

Leaf Scorch:

This disorder occurred due to the Potash deficiency and affected plant showed scorching of old leaves at the tips and margins. This condition is most common during the winter months. It is caused by an excess of chloride ions which render Potash unavailable. This disorder is common in saline soil or brackish water is used for irrigation or muriate of potash is applied as a fertilizer to meet the Potash deficiency.

Diseases:

Anthrachnose: (Also known as mango blossom blight or bird's eye spot disease). This is also a fungal disease, more especially in humid and high rainfall areas. The leaves, shoots, inflorescence and the fruits are all affected by it. The symptoms is appearance of black necrotic areas on the affected parts. The affected young shoots finally show die-back symptoms. If the fungus attacks the fruits at maturity, the disease appeared in storage. As the fungus survives on dead or dried twigs, these should be pruned and burnt at the earliest. The disease can also be controlled by spraying Bordeaux Mixture (3:3:50), blitox(0.3%) trice a year, i.e. February, April and September when affected full mature fruits should be dipped in hot water (51°C) for 15 minutes before storage.

Powdery Mildew: It is the most serious disease of mango. This fungal disease is widely prevalent in all mango growing regions and can even completely destroy the crop. This is occur early during the flowering stage.

Insect-pests:

Mango Hoppers- This is the most damaging insect during the flowering season. Both adults and nymphs are damaging stage. They suck the sap from tender shoots and panicles. The hoppers hiding in the bark of plant and active during the flowering stage. Its incidence is favoured by high humidity accompanied by cloudy weather and low night temperatures during the period between panicle development and fruit set. It can be controlled by an application of wettable

sulphur (0.2%) / Karathene (0.1 %)/Bavistin (0.1%).The first spray should be given at pre-bloom stage, as a preventive step, in areas more prone to the incidence of this disease. If necessary, this may have to be followed by two more applications at full bloom and fruit set stages (at fortnightly intervals).

Mango Mealy Bug: This is the second most damaging insect. Female lays eggs during May during May under soil clods, around the tree trunk, up to a depth of 5-15 cm. The nymph emerge in December-January and start climbing up the tree where they congregate together and suck juice from young shoots, panicles and flower pedicels.

Mango Stone Weevil: This is mostly prevalent in the southern parts of the country.

Leaf Cutting Weevil: This cuts the newly emerged leaves (mostly in rainy season) at the base of the lamina in the form of a clear and sharp cut.

Fruit -Fly: It is serious pests as the affected fruits become unfit for consumption. The fruit-fly lays its eggs in clusters of 150-200 under the skin of the fruit just before ripening.

Harvesting: The mango fruit show simple sigmoid growth pattern. It is a climacteric fruit hence, harvesting of fruit to be correct stage. The various criteria recommended for judging maturity are

- Slight colour development on the shoulder
- When one or two ripe fruits fall from the plant naturally (Tapka stage)
- When the specific gravity of fruits ranges between 1.01 and 1.02(Singh, 1960)

Yield: It is a highly variable factors depending upon the cultivars and age of the plants, climatic conditions, incidence of pests and diseases. The plant start bearing at the age of 4-5 years (15-20 fruits) and the optimum crop starts from the 10th year when each tree yields about 400 to 600 fruits.

Storage: The mango fruits can be store successfully at 7-9 °C with RH 90% for seven weeks.

MILLETS: MARVEL GRAIN OF FUTURE

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Introduction

The millets are being celebrated over the world on people's plates and palates, and we Indians are experiencing their return because we were formerly associated with them. India will achieve food and nutritional security under IYM 2023. Millets are regarded as 'Smart Food' since they are simple to grow, largely organic, and have a high nutritional value. With PM Modi's vision of "Vasudaiva Kutumbakam" (The World is One Family) and the goal of making IYM 2023 a "People's Movement," India will have the chance to promote Nutri-cereal Millets internationally and put them on the "food map" of the world while also establishing India as the "Global Hub for Millets."



We are experiencing a new paradigm shift on a global scale that is related to our eating habits, climate change, and new millets trading trends. To raise awareness, boost production, and promote consumption of millets, we are honouring 2023 as the year they return to our farms and plates. One of the main goals of this celebration is to generate "Millet Mindfulness" via increasing awareness.

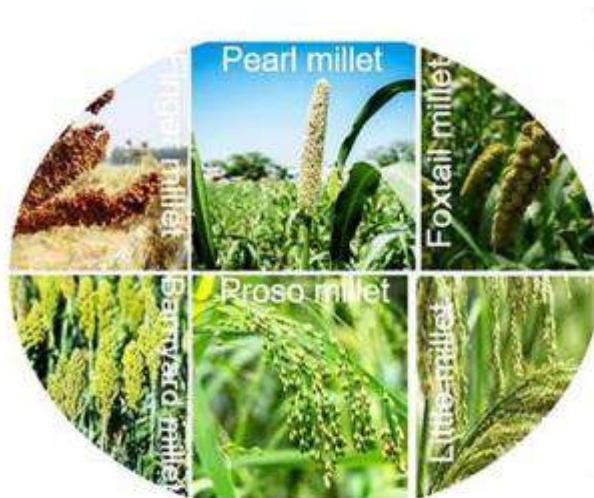
A plant in the Graminae (Poeceae) family called millet may grow in semi-arid regions and requires less water for irrigation, which will aid in water management. Quinoa, millet, and sorghum are three widely recognized crops for their resilience to adverse weather conditions.

Major millets

- ✓ Sorghum (Jowar)
- ✓ Pearl Millet (Bajra)
- ✓ Finger Millet (Ragi)

Minor Millets

- ✓ Foxtail millet (Kakum)
- ✓ Kodo millets (Kodon)
- ✓ Barnyard millet (Sanwa)
- ✓ Little millet (Kutki/Shavan)
- ✓ Proso millet (Chenna/Barri)



Health Benefits of millets

Due to their extremely high nutritional content, millets are commonly referred to as nutri-cereal. In comparison to rice, they contain 30–300% more nutritional components like calcium, minerals, iron, fibre, beta-carotene, and numerous other micronutrients. Millets, which are gluten-free and have a low GI (glycemic index), are suitable for persons who have wheat allergy or intolerance since they are high in B vitamins, calcium, iron, potassium, magnesium, and zinc. Millets are also a good option for diabetics and anyone who are gaining weight. The phenolic properties found in millets comprise phenolic acids, flavonoids, and tannins, which are beneficial to human health.



Pearl Millet (*Pennisetum glaucum*) Bajra

Pearl millet is a superfood that reduces cholesterol, blood sugar levels, promotes weight loss, reduces constipation, prevents insomnia, is the best plant-based source of protein, is high in antioxidants, and heals iron deficiency anaemia.

Finger Millet (*Eleusine coracana*):Ragi/Madua

Finger millet is full of dietary fiber, which helps to regulate the “bad” cholesterol that can contribute to heart diseases like atherosclerosis. Soluble fiber absorbs cholesterol before it enters your bloodstream, maintaining a lower cholesterol level.

Foxtail Millet (*Setaria italica*) Kangani/Kakun

Foxtail Millet is rich in Vitamin B₁₂ which is important for maintaining a healthy heart, smooth functioning of the nervous system, and in general good for skin and hair growth. Foxtail millet may enhance glycemic control, lower insulin levels, and lower cholesterol.

Sorghum (*Sorghum bicolor*) Jowar

Gluten-free, high in fibre, great for diabetics, a source of protein, loaded with vital minerals, encourages bone health, aids in weight loss, protects the health of the digestive system, a fantastic source of protein for vegetarians and vegans, high in antioxidants, a grain with a huge variety of uses, and more sustainable than other grains.

Kodo Millet (*Paspalum scrobiculatum*)

Millet, which are naturally high in fibre, also aid in reducing symptoms of constipation, flatulence, bloating, and stomach cramps. A good source of magnesium, which is believed to support heart health, is millets. Blood pressure is lowered as a result.

Proso Millet (*Panicum miliaceum L*)

When used as food for humans, proso millet offers many advantages. Proso millet contains high levels of vitamins, minerals, dietary fibre, polyphenols, and proteins. Because it is gluten-free, it is perfect for those who cannot tolerate gluten. Lecithin, which helps the neurological health system, is abundant in proso millet.

Barnyard Millet (*Echinochloa esculenta*)

Low glycemic index, gluten-free, high in dietary fibre, and a good source of iron

Little Millet (*Panicum sumatrense*)

Magnesium is rich in little millet, which helps maintain good heart health. Additionally, it has a lot of niacin, which reduces cholesterol. Little millet includes phosphorus, which is

excellent for promoting weight loss, tissue healing, and energy synthesis during intense exercise. It also helps detoxify the body.

Application

Millets are a sustainable food source to battle hunger in a changing world since they are resistant to environmental stress, pests, and diseases. Because millets use little water or other resources, they are a long-term alternative for slowing down global warming and developing agri-food systems that are climate resilient.

Nutri-cereals have high concentrations of iron, folate, calcium, zinc, magnesium, phosphorus, copper, vitamins, and antioxidants. Millets are a great source of dietary fibre. They have been shown to lower the risk of heart disease and diabetes in adults, in addition to being crucial for children's healthy growth and development. Because they don't contain gluten and have a low glycemic index, millets are beneficial for diabetes. They can also aid in the prevention of dietary deficits and cardiovascular disease.

Conclusion

Millets are more than just ancient grains making a comeback and they're a smart, sustainable answer to the modern world's food and health challenges. With their exceptional nutritional value, resilience to climate change, and low environmental footprint, millets offer a sustainable solution to the growing challenges of food security, malnutrition, and environmental degradation. Millets have all the qualities needed to become the staple grain of the future. As we look for ways to eat healthier and live more sustainably, it's time we put these humble grains back on our plates and back in the spotlight.

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SEAFOOD AND MICROPLASTICS: A HIDDEN HEALTH THREAT FROM OCEAN TO PLATE

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Abstract

Seafood is essential in developing sustainable food systems due to its rich nutrients, lower environmental impact, support for vulnerable communities, and potential to decrease dependence on less healthy meat options. Despite these advantages, seafood can accumulate contaminants, including microplastics, which have garnered global attention due to harmful effects on humans and the environment. Growing concerns about microplastics may hinder meeting future global food security needs. In 2023, global plastic materials production reached 442 million metric tons (MMT), 295 times more than in 1950. Poor management and waste discharge result in plastic entering marine ecosystems, disrupting environments, and causing toxicity that magnifies the food chain, affecting human health. Microplastics enter the human body through routes including seafood consumption, causing adverse health effects like immunotoxicity, inflammation, neurotoxicity, gut microbiome disruption, and cell damage. This technical article details microplastic sources in seafood and their levels across species, highlighting health impacts and strategies for mitigating pollution to help regulatory bodies reduce environmental plastic pollution and limit bioaccumulation in food products.

Keywords: Microplastic pollution, Seafood safety, Bioaccumulation, Human health, Management

Introduction

Global plastics production is projected to reach 1.2 billion metric tons by 2060, a sharp rise from 442.5 million tons in 2013. Yet, only 9% of plastics are recycled, while the rest end up in landfills, incinerators, or are dumped. About 22% of global plastic waste enters oceans illegally (Kushwaha et al., 2024). Oceans currently contain an estimated 5 to 13 million tons of plastic; by 2050, plastic may outweigh fish in the sea. Microplastics (MPs), which are plastic fragments smaller than 5 mm, are of growing concern due to their persistence and widespread presence in marine life. The seafood industry produced 179 million tons in 2018, with 88 million tons consumed by humans, providing essential nutrients like protein, omega-3 fatty acids, and key minerals. In some coastal communities, fish accounts for up to 70% of animal protein intake. MPs have been detected in various marine species and organs, and their ingestion through seafood may pose health risks. The UN's Sustainable Development Goal 14 highlights the urgent need to curb marine pollution, including microplastics (Walker, 2021). This article explores microplastic pollution's sources, impacts, and health implications in marine ecosystems.

Source of Microplastics

The main contributors to microplastics (MPs) in marine settings are synthetic fibers, personal care items, tires, plastic pellets, wastewater discharge, and byproducts. According to Galafassi et al. (2019), around 80% of marine plastic debris comes from plastic materials entering water bodies. Figure 1 depicts the source of plastics/microplastics in marine environments. Microplastics from personal care products contain thousands of microbeads per gram and enter water systems through drainage. Industrial discharge and wastewater facilities contribute to MP pollution, with most MPs ultimately reaching oceans through rivers.

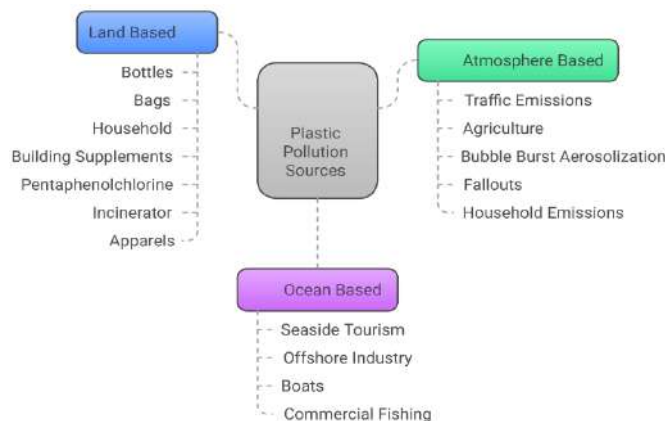


Fig .1. Pathway of Microplastics (MPs) in Marine Environment

Bioaccumulation of MPs in Seafood

Lusher et al. (2017) reveal that fish can unintentionally consume microplastics, mistaking them for natural prey. The similarity between microplastics and plankton makes them susceptible to ingestion by fish species. Filter-feeding fish are particularly at risk of ingesting microplastics due to their feeding behavior (Wang et al., 2019). Trophic transfer occurs when fish consume organisms that have already ingested microplastics (Nelms et al., 2018). This bioaccumulation results in higher microplastic concentrations in predatory fish. The transfer efficiency depends on particle characteristics and species' digestive physiology. Bivalve mollusks, like mussels and oysters, are filter feeders that accumulate microplastics.

Occurrence of MPs in Seafood

Rising levels of microplastics in the marine environment have sparked concerns about seafood safety. As plastic fragments are discovered in oceans, understanding their interactions with marine life and implications for human consumers is crucial. Microplastics accumulate within marine food webs, affecting ecological health and human seafood consumption. Bioaccumulation involves microplastic buildup in animal tissues through direct intake, ingestion of contaminated organisms, and absorption through body surfaces (Wright et al., 2013). Biomagnification refers to increased concentrations up the food chain as lower trophic organisms are consumed by predators (Nelms et al., 2018). Rochman et al. (2015) reported microplastic transfer from prey to predator in laboratory conditions. Likewise et al. (2014) demonstrated microplastic transfer across three trophic levels in marine food webs. These findings suggest species higher in the food web may contain higher microplastic levels. Several factors influence bioaccumulation and biomagnification. Particle size affects ingestion by invertebrates and tissue translocation. Polymer types have varying affinities for contaminants and different residence times. Environmental factors like temperature, pH, and salinity affect pollutant adsorption on microplastics (Wang et al., 2016). Persistent organic pollutants (POPs) bioaccumulate with microplastics and are biomagnified through trophic levels (Teuten et al., 2009).

The ingestion of microplastics (MP) by commercially significant seafood species threatens human food safety. Microplastic ingestion has been documented in economically important species across taxonomic groups and feeding guilds. Studies by Lusher et al. (2013) and Neves et al. (2015) demonstrated microplastic ingestion in commercial fish species such as cod, haddock, mackerel, and tuna. Rochman et al. (2015) found microplastics in 28% of

individual fish and 55% of species from fish markets in Indonesia and California. Shellfish, particularly bivalves, are vulnerable to microplastic ingestion through filtering. Li et al. (2015) reported microplastics in 17% of oysters and 33% of mussels in Chinese coastal areas. Devriese et al. (2015) described crustaceans, such as shrimp and crabs, that ingested microplastics. The frequency of microplastic ingestion varies among species and locations, influenced by feeding mode, habitat, and environmental concentration. Microplastic consumption by commercial species causes physical, chemical, and biological effects. Physical effects include intestinal obstruction and feeding depression. Watts et al. (2015) demonstrated decreased food consumption in shore crabs when microplastics were ingested. Chemical effects arise from plastic additives or persistent organic pollutants (POPs) on MP. Rochman et al. (2013) observed liver stress in fish after exposure to polyethylene microplastics containing contaminants.

Biological effects include alterations in gut microbiome composition and impacts on reproductive success. These findings have implications for seafood industry viability, including stock health, quality, and safety concerns, as well as monitoring measures. There could be consequences for consumer perceptions and regulatory approaches. While evidence suggests adverse health effects, challenges remain in understanding microplastic exposure toxicology. The EFSA Panel on Contaminants in the Food Chain (2016) highlighted research limitations, including difficulties in establishing interpretation guidelines and distinguishing effects from other pollutants. Nelms et al. (2018) emphasized the need for research on chronic exposure effects, given potential bioaccumulation in tissues. Standard protocols should be established for detecting microplastics in human tissues to enhance understanding of exposure and health implications.

Effects of MPs on Human Health

Microplastics in marine environments and their entry into the human diet via seafood have become a growing health concern. Direct ingestion is considered the primary exposure route, with studies confirming the presence of microplastics in human stool, indicating dietary exposure. These particles can cross biological membranes, accumulate in tissues, and pose physical, chemical, and biological risks—including inflammation, hormonal disruption from additives like phthalates and bisphenol A, and exposure to heavy metals and persistent organic pollutants. Microplastics also harbor harmful bacteria and may alter gut microbiota, impacting digestion and immunity. Despite increasing evidence, knowledge about long-term human health

effects remains limited, and more research is needed to assess chronic exposure risks.

Conclusion

Formulating microplastics regulations is challenging due to limited knowledge of their health and environmental impacts. Data on human health risks remain scarce, though microplastics may cause inflammation and oxidative stress. They accumulate in marine environments, contaminating seafood and becoming harder to detect as they degrade. Effective regulation requires improved detection methods, long-term toxicity studies, and public awareness. Measures like content labeling and education campaigns could help reduce plastic pollution (Barboza et al., 2018).

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PESTS OF CROSSANDRA AND THEIR MANAGEMENT

Article ID: AG-VO5-I05-75***Dr. M. Devi and Mr. D. Ravichandiran**

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Introduction

Crossandra is an herbaceous perennial ever green semi shrub growing to a height of 4ft. commonly called 'Fire Cracker' plant, it is an important commercial loose flower crop. The flowers are of great demand for use in hair adornments and in the form of garlands, venis and gajras. Though not fragrant, crossandra flowers are very popular because of their attractive bright colour, light weight and good keeping quality. It is a popular loose flower crop in the country, more particularly in the southern region, occupying nearly 15 per cent of the area under traditional flowers in Southern states. In this crop various pests are attacked and it may reduce the flower yield mainly due to spike borer and crossandra bug etc.

The gram caterpillar *Heliothis armigera* Hb. (Noctuidae, Lepidoptera)

The larva of this polyphagous species feeds on the leaves, spike-lets, flowers and developing seeds. The early instar larvae bite holes in the spikelet's whereas full-grown ones feed on the mature spikes. It is noticed occasionally on the crop.

Management

- Spray dimethoate @ 2ml/lit, acephate @ 1.5 ml / lit.
- Neem seed kernel extract is applied.
- Use clean seeds.
- Sowing of resistant varieties.
- Flooding the soil.

- Cleaning the field and removal of all undesired plants, plant debris and other material from the field.
- Neem oil -0.5 % with teepol – 1 ml /lit.
- The insecticide like imidacloprid, chlorpyrifos, thiamethoxam.



Crossandra

Crossandra Bug: *Cynenida affinis*, Pentatomidae, Hemiptera.

Symptoms:

- Suck the sap of the plant mainly the tender leaves.
- The infested parts followed by drying & drooping of the affected parts. The damage of the affected parts.
- The damage also extends to spikes as well as brown lesions seen on the infested plants.

Identification of the pests:

- These are small bugs with greenish, brownish, marking on the body.
- Both the nymphs and adult suck the sap.
- Egg: yellowish white in colour.
- Nymph: reddish brown in colour.
- Adult: the bug is similar to that of the nymph, that is red in colour.

Management:

- Dimethoate 30 EC @ 1lit/ ha.
- Methyl demeton and phosphamidon 25 EC @ 1 lit /ha.
- Biological control- Predators, parasitoid.

Brown scale and white scale: *Saissetia nigra*, Coccidae ,Hemiptera.

Symptom:

- It infests tender leaves, shoots and twigs.

- Dome shaped and brown scales will be seen on the under surface of leaves especially of young plants.
- The infested leaves become discoloured and completely yellowish and finally may fall down.

Identification of pest: Female adults are elliptical, flattened and shiny black.

Management:

Cultural practices:

- Use clean seeds.
- Sowing of resistant varieties.
- Flooding the soil.
- Cleaning the field and removal of all undesired plants, plant debris and other material from the field.

Biological measures: *Cryptolaemus montrozieri* @ 20 / plant. Parasitoid – *Aneristis* sp.

Chemical measures: Application of carbofuran granules at 1 kg a.i /ha and spraying of dimethoate @ 2ml /l or acephate @1gm/1l or chlorpyrifos 0.05% at fortnightly intervals.

Physical measures:

Hand picking: Method of choice when pests are slowly crawling and are not able to fly. Collection & destroy of the infected plants.

Trapping: Used for flying pests which can't be picked by hand or burned.

Burning: Is used for flying pests which can't be picked by hand & can cause damage pests are burned & waste is removed frequently.

Mealy Bug: *Ferrisia virgata*, Pseudococcidae, Hemiptera.

Symptom:

- cottony mealy bugs are seen on the infected plants.
- Nymphs & adults suck the sap & weaken the plants.
- Stunted growth of the plant.
- Sucking of the plant sap.
- Large number of insects remains in leaf sheath & sucks the sap.

Identification of pest:

- Egg: yellowish white eggs / simply deposits nymphs in outer leaf sheaths.

- Nymph: pale yellowish nymph is active & crawls about the plant.
- Adult: Nymphs & adults being wingless look alike.
- Wingless insect covered with filamentous material.
- Female are reddish, oval, soft bodied living in colonies.
- Males are small, slender, pale- yellow, having single pair of wings and style like process at the end of the abdomen but lack mouthparts.

Management:

- Fish oil roselin soap – 25g/lit.
- Neem oil -0.5 % with teepol – 1 ml /lit.
- The insecticide like imidacloprid, chlorpyrifos, thiamethoxam.
- Remove & destroy the affected plants.
- Conserve the natural enemies like *scymnus sp.*, *Anathichus pygmaeus* & *Mepachymerus ensifer*.
- Spray dimethoate 2 ml /l or acephate @ 1gm /lit.

White Flies: *Lipaleyrodes sp.*, Aleyrodidae, Hemiptera

Symptom:

- It occurs in large numbers on the under surface of the leaves.
- The chlorotic spots are formed on leaves & coalescence.
- Defoliation takes place.
- Sooty mould disease is formed.

Identification of pest:

- Egg: The eggs are laid in concentric circle shapes.
- Nymph: Greenish yellow, oval outline.
- Adult: yellow body covered with waxy bloom.

Management:

- Summer ploughing is done to destroy the eggs of the whiteflies.
- Installing yellow sticky traps.
- Spray dimethoate @ 2ml/lit or acephate @1gm /lit or phosalone 0.05% or Fenthion 0.05% at fortnightly interval repeated twice.

Aphid: *Aphis sp.*, Aphididae, Hemiptera.

Symptoms:

- The insect sucks the chlorophyll of the leaves.
- It leads to yellowing of leaf.
- It leads to sooty mould diseases.
- Honey dew like secretion from the infected plant.
- It leads to invasion of ant.
- It may cause the elongation of petiole.

Identification of pest:

- Both nymph & adult suck the sap from tender leaves and inflorescence.
- The infested inflorescence fails to open and the leaves dry off.
- Adult – small, soft bodied & pearl shaped insects.

Management:

- Yellow sticky trap.
- Natural enemies viz, *cocciniella*, *Crysoperla cornea*.
- Spray dimethoate @ 2ml/lit, acephate @ 1.5 ml / lit.
- Neem seed kernel extract is applied.





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REJUVENATION IN LITCHI ORCHARD: A PRACTICAL APPROACH FOR REVIVING PRODUCTIVITY

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Introduction

Litchi (*Litchi chinensis* Sonn.) is a commercially significant fruit crop in India, cherished for its luscious, aromatic fruits and high market value. With India ranking as the second-largest producer globally—Bihar being the leading state—litchi plays a vital role in the livelihoods of many fruit growers. However, over time, orchard productivity tends to decline due to aging of trees, poor canopy management, and pest or disease accumulation. This leads to reduced yields, inferior fruit quality, and increased management difficulties. One of the most effective, low-cost strategies to counter these challenges is the rejuvenation of old and senile orchards. Instead of uprooting and replanting—which requires substantial time and investment—rejuvenation offers a scientific and sustainable approach to restore vigor and extend the productive life of existing trees. Through systematic pruning, careful shoot selection, integrated nutrient management, and pest/disease control, orchard performance can be significantly enhanced within a span of 2–3 years.

Need for Rejuvenation

With time, litchi trees tend to grow tall and develop dense, unmanageable canopies. This leads to:

- Aging of trees leading to reduced fruiting wood.
- Overcrowded and unmanageable canopies.
- Poor light penetration and air circulation,
- Increased pest and disease incidence,

- Low flowering and fruiting,
- Reduced fruit size and quality,
- Difficulty in carrying out orchard operations like spraying and harvesting.

Rejuvenation involves a series of practices aimed at restoring the tree's health and productivity. It is not only a cost-effective alternative to replanting but also a sustainable solution to enhance fruit quality and extend the orchard's lifespan.

(i) This should be carried out only when required

Litchi plants typically start bearing fruit after 5-6 years, reach commercial bearing at 10 years, and have a productive lifespan of 11 to 40 years. At the commercial stage, proper management through pruning, canopy training, nutrition, irrigation, and pest control is essential for quality production. Orchards over 30-40 years old, even with a 10m x 10m spacing, often develop dense canopies, with fruiting only at the top. This creates challenges in pest control and harvesting, making it difficult to assess tree longevity. Additionally, maintaining orchards older than 40 years can become uneconomical. Rejuvenation is needed to enhance productivity and quality. Before selecting trees for rejuvenation, assess their health, location, and value. Only trees with healthy trunks, intact bark, and live wood should be selected. If these conditions aren't met, rejuvenation will not be effective.

(ii) Raising Awareness Among Growers About Its Importance

Given the benefits and challenges of rejuvenation, it is crucial to first train orchardists in scientific methods and best practices. Proper training enables them to apply rejuvenation techniques effectively and confidently. Litchi trees have strong regenerative potential, and rejuvenation offers a faster return on investment—reaching breakeven in just two years, compared to 10–12 years for new orchards. Well-managed rejuvenated trees can continue producing high-quality fruit for another 12–15 years, comparable to newly established commercial orchards.

(iii) Repairing of Wounds

Exposed wounds on trees can attract disease-causing organisms from the surrounding environment, so they must be treated properly to promote healing. For small wounds, painting with a disinfectant or color may be sufficient. For larger hollows, the diseased or rotten inner parts should be scraped out, the exposed area smeared with coal tar, and then filled with bricks and kankar. Finally, the area should be plastered with cement to seal and protect it.

(iv) Pruning: The Foundation of Rejuvenation

Pruning is one of the most critical practices in rejuvenating old litchi trees. It involves removing dead, diseased, or overgrown branches and reshaping the canopy to promote better air circulation, sunlight penetration, and overall tree health. The process should be carried out carefully to avoid damaging the tree.

Reiterative Pruning Technique

Reiterative pruning is a heavy pruning technique that focuses on cutting back the tree to stimulate new growth. The process involves:

- **Timing:** The best time to perform reiterative pruning is in August-September, immediately after the rainy season. This allows the tree to recover quickly and regenerate during the following growing season.
- **Procedure:** Pruning should be done at a height of 2 to 3 meters, depending on the tree's trunk size. Typically, 3 to 5 main branches with outward growth are chosen for pruning to create an umbrella-shaped or semi-circular canopy.
- **Aftercare:** After pruning, it's crucial to treat the exposed areas with a Bordeaux mixture or Copper-oxychloride (Blitox) to prevent infections. The tree should also be watered and fertilized to promote healing and growth.

(v) Nutrition Management: Essential for Growth and Productivity

A proper nutrition schedule is vital for litchi tree rejuvenation. After pruning, trees need adequate nourishment for recovery and growth. Fertilizers should be applied using the ring method, with doses of 75–80 kg of well-rotted farmyard manure, 2 kg of neem or castor cake, 1 kg of urea, 1.5 kg of single super phosphate, and 500 g of muriate of potash. These should be split into two applications: one in August–September and another in February–March. Additionally, foliar sprays of zinc (2–3 g/l) and boron (2 g/l) should be applied starting a year after pruning to support enzyme activity, chlorophyll production, and flower development.

(vi) Irrigation: Ensuring Proper Water Supply

Irrigation is crucial for the health of rejuvenated litchi trees, helping them absorb nutrients, heal pruning wounds, and support new growth. Drip irrigation is recommended to efficiently deliver water to the root zone. Trees should be irrigated regularly, especially during dry spells, and immediately after fertilizer application. In summer, irrigation every 8-10 days and every 15-16 days in winter encourages faster growth and better canopy development. Irrigating

intercrops benefits both the trees and soil health. Mulching in April-May and September-October helps conserve moisture, reduce irrigation frequency, and promote growth.

(vii) Thinning and Canopy Development

After pruning in August, vegetative sprouts begin to emerge within 25-30 days in cv. *Shahi* and 40-45 days in cv. *China*. A large number of branches grow, covering the entire pruned tree. At this stage, thinning is necessary to develop a solid, semi-circular, or open umbrella-shaped canopy. Shoots should not be removed immediately after emergence; they should be pruned after 6-8 months. The sucker growth at the base should be removed, and excessive branches thinned, leaving 3-4 strong branches on each pruned limb. These branches should project in all directions, and the tree should be trained to achieve the desired shape, ensuring good air and light penetration throughout. **Horizontally** growing limbs should be pruned to prevent them from sagging under fruit weight.

(viii) Pest and Disease Management

Effective plant protection is vital for the healthy growth of rejuvenated litchi trees. Early intervention is key, as pests like leaf rollers, miners, and leaf-cutting weevils begin damaging new growth soon after pruning. Spraying Lambda cyhalothrin (1.5 ml/l) or Cypermethrin (2.0 ml/l) 2–3 times during new flush emergence helps control these pests. Mites can be managed with Omite (3 ml/l) in September–October and February–March. Bark-eating caterpillars should be treated early with insecticides; at advanced stages, clean the tunnels, insert Trizophos or kerosene-soaked cotton, and seal with mud. Copper fungicide sprays in October and March prevent fungal diseases, while applying Bordeaux paste to the lower trunk protects against multiple pests.

(ix) Fruit Yield and Quality

Although old, non-rejuvenated litchi trees may produce higher yields, the fruit quality is often poor—smaller in size, more wastage, and prone to physiological disorders and pest-disease attacks—resulting in low market value. In contrast, rejuvenated trees produce fruits with improved yield quality and better physio-chemical characteristics. However, a slight delay in the maturity period is observed in rejuvenated trees.

Conclusion

Rejuvenating old litchi orchards is a practical and cost-effective approach to restore productivity and extend the lifespan of the trees. Through a combination of pruning, proper



nutrition management, irrigation, and pest control, orchardists can revive their orchards, ensuring high-quality litchi production for many years. By following the scientific methods outlined in this article, orchardists can ensure that their litchi trees remain healthy, productive, and economically viable long into the future.



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SPEED BREEDING: FAST-TRACKING THE FUTURE OF CROP IMPROVEMENT

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Abstract

In the face of climate change, growing global populations and limited agricultural land, enhancing the pace of crop improvement has become a critical priority. Speed breeding is a technology-driven approach that enables multiple plant generations per year instead of the traditional one or two. By manipulating environmental conditions such as light duration, temperature and humidity in controlled growth chambers, speed breeding drastically shortens the breeding cycle. This technique, initially demonstrated in wheat by the John Innes Centre, has now expanded to a wide array of crops, including barley, chickpea, canola and even horticultural plants. Its integration with genomic selection, CRISPR-Cas genome editing and high-throughput phenotyping offers a powerful toolkit for modern plant breeders aiming to deliver improved, climate-resilient, high-yielding cultivars at unprecedented speed. Speed breeding not only accelerates genetic gains but also supports rapid disease resistance screening, trait fixation and hybrid development. It also enables pre-breeding and functional genomics studies to progress more swiftly. Despite its promise, the technique demands considerable infrastructure, energy input and technical expertise, especially in resource-limited regions. However, ongoing innovations in LED technology, low-cost automation and open-access protocols are improving its accessibility. This article explores the principles, applications, challenges and future potential of speed breeding. As agriculture races against time to meet 21st-century demands, speed breeding offers a glimpse into a future where innovation bridges the gap between science and food security.

Keywords: Speed breeding, crop improvement, rapid generation cycling, controlled environment, plant biotechnology and climate resilience

Introduction:

Crop improvement has historically been a slow process, with breeders waiting months or even years to achieve a single generation of plants. Traditional breeding methods, constrained by seasonal cycles, limit how fast new, high-yielding or stress-resilient varieties can reach farmers. As the world grapples with escalating climate pressures, pest evolution and the urgent need for food security, the agricultural community is turning to innovative tools that can fast-track breeding outcomes. One such breakthrough is **speed breeding** (Kersey, 2019).

Originally developed by researchers at the John Innes Centre in the United Kingdom, speed breeding involves the use of **extended photoperiods**, optimized temperatures and controlled humidity to accelerate plant growth and flowering. Under these controlled conditions, crops like wheat, barley and chickpea can complete a generation in just 6 to 8 weeks. By fitting multiple generations into a single year up to six for some species, the speed breeding radically transforms the breeding timeline (Tester and Langridge, 2010 & Watson *et al.* 2018)

This innovation has been particularly impactful when combined with modern technologies like marker-assisted selection, CRISPR gene editing and genomic selection. It allows breeders to fix traits faster, test crosses sooner and respond rapidly to emerging agricultural challenges such as drought or disease **outbreaks**. While initially limited to temperate crops, speed breeding protocols are now being optimized for tropical and subtropical crops, increasing their global relevance (Voss-Fels *et al.* 2019)

The promise of speed breeding lies not only in its scientific efficacy but also in its potential to ensure timely delivery of improved varieties to farmers. As a tool of modern agriculture, it stands at the intersection of urgency, innovation and sustainability.

What is Speed Breeding?

Speed breeding is a cutting-edge technique that accelerates plant growth and reproduction by manipulating environmental conditions, like light duration and temperature. By extending daily light exposure to as much as 22 hours and maintaining optimal climate conditions, researchers can dramatically shorten the time it takes for crops to flower, set seed and mature. Originally inspired by plant-growing experiments conducted by NASA for space missions, the concept has since been adapted and refined for agricultural use here on Earth. The goal is simple

but revolutionary: reduce generation times and allow multiple crop breeding cycles within a single year (Ghosh *et al.* 2018, Hickey *et al.* 2017 and Kang, 2019).

Using **controlled-environment facilities** such as growth chambers or specialized greenhouses, speed breeding enables:

- Earlier flowering
- Faster seed development
- Up to 4–6 generations per year, depending on the crop

This increase in breeding cycles significantly boosts the number of selection opportunities within a given time frame, accelerating genetic gain and the development of improved crop varieties.

How Speed Breeding Works?

Speed breeding relies on controlled environments that accelerate the growth cycle of crops by fine-tuning key environmental factors. The system typically includes the following essential components:

- **Extended LED Lighting:** Mimics long daylight hours (up to 22 hours) to trigger earlier flowering and rapid vegetative growth.
- **Environmental Controls:** Maintains optimal temperature and humidity levels throughout the growth cycle, enabling year-round cultivation without reliance on seasonal changes.
- **Automation and Monitoring:** Advanced systems regulate irrigation, nutrient supply, and climate data, ensuring consistency and reducing manual labour.

Under traditional open-field conditions, plant breeders are limited to one or two generations per year. In contrast, speed breeding facilities make it possible to produce **four to six generations annually** in crops such as wheat, barley, chickpeas and canola. This drastic reduction in generation time significantly accelerates the development of improved, climate-resilient crop varieties (Ballini *et al.* 2013 & Collard and Mackill, 2008).

Applications and Benefits of Speed Breeding:

- **Shortened Breeding Cycles:** Achieving 4–6 generations per year versus 1–2 traditionally.
- **Enhanced Selection Efficiency:** Enables quicker evaluation of desired traits.
- **Integration with Genomic Tools:** CRISPR and marker-assisted breeding can work synergistically with speed breeding.

- **Stress Testing:** Rapid screening under stress conditions like salinity or drought.
- **Functional Genomics:** Accelerates gene discovery and validation.
- **Pre-breeding & Introgression:** Useful for transferring traits from wild relatives into elite germplasm.

Integration with Modern Breeding Tools

Speed breeding works best when combined with:

- **Genomic Selection:** Predicts plant performance using genetic data.
- **Marker-Assisted Selection:** Targets known genes for desired traits.
- **CRISPR and Gene Editing:** Precisely alters DNA to develop new traits.

This integration reduces breeding timelines by **50–70%** for complex traits.

Challenges and Limitations:

- High infrastructure costs for lighting and temperature control.
- Energy demands and carbon footprint in non-sustainable setups.
- Genotype-specific responses to controlled environments.
- Limited adoption in resource-constrained breeding programs.

Crops and Success Stories

Speed breeding has shown success across a wide range of crops:

- **Wheat and Barley:** Generation time reduced to 6–8 weeks.
- **Chickpea and Lentil:** Adapted for multiple cycles per year.
- **Canola and Pea:** Rapid breeding of disease-resistant lines.
- **Rice and Sorghum:** Protocols under development for tropical species.

Institutions like CIMMYT, ICARDA and ICRISAT are adopting speed breeding in their global breeding programs (Zhang, *et al.* 2020).

Future Prospects:

- Integration with AI-driven phenotyping.
- Use of solar-powered systems for sustainability.
- Development of open-source hardware/software for low-cost implementation.
- Customization for orphan crops and underutilized species.
- Broader global collaboration for equitable access.
- Need for skilled personnel for optimal protocol implementation.

Conclusion

Speed breeding is more than just a tool for faster plant growth—it's a foundational platform for **next-generation crop improvement**. Its ability to synergize with genomic tools, enable stress simulations and hasten the integration of novel traits makes it a transformative approach in both research and applied breeding. As the demand for climate-resilient, high-yielding crops intensifies, speed breeding stands out as a vital solution to meet agricultural challenges swiftly and sustainably.

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THE JOURNEY OF SRI THOTA NAGESWAR RAO TOWARDS MECHANIZED AND SUSTAINABLE FARMING

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Introduction

Sri. Thota Nageswar Rao, a 59-year-old progressive farmer from Jajaravelli village in Kannepalli Mandal of Mancherial district has become a beacon of innovation in agricultural practices through his consistent efforts, resilience and willingness to embrace change. Born on January 1, 1965, he has over 30 years of experience in farming. He has completed formal education up to the 10th standard and has since dedicated his life to agriculture, the primary source of livelihood for his family. Owning 11 acres of land (5 acres rainfed and 6 acres irrigated) with black cotton soil and a pond as the main irrigation source, Sri Rao cultivates a wide range of crops. His cropping pattern includes paddy (varieties like Jaisriram and MTU 1010), cotton (Nuziveedu - Asha), soybean, redgram, vegetables, sesamum, green gram, and black gram in both Kharif and Rabi seasons.

Mechanization and Innovation

Recognizing the limitations and challenges of traditional transplanting methods especially high labour costs, water scarcity and declining soil health. Sri Rao sought more efficient alternatives. His proactive approach led him to contact scientists at Krishi Vigyan Kendra (KVK), Bellampalli where he underwent training and participated in live demonstrations on farm mechanization and direct-seeded rice (DSR) techniques.

Inspired by these interventions, he adopted a seed-cum-fertilizer drill for sowing operations. He initially used this implement to sow paddy directly in one acre of land under an On-Farm Trial (OFT) which later expanded to four acres due to its success. He further customized spacing in

the seed drill to sow other crops like redgram, soybean and green gram. His innovative approach also influenced fellow farmers who have started using the same technology in their fields.

Farm Machinery and Cost Efficiency

Sri Rao owns several modern implements including a tractor, cultivator, plough, seed drill (Goru) and combine harvester. His transition to mechanized farming has led to considerable cost savings and operational efficiency. For example, in paddy cultivation:

Particulars	Transplanted Rice	Direct Seeded Rice (DSR)	Savings (Rs./acre)
Human Labour	Rs. 7,500	Rs. 4,000	Rs. 3,500
Machine Usage -		Rs. 2,000	(-) Rs. 2,000
Seeds	Rs. 2,000	Rs. 3,200	(-) Rs. 1,200
Fertilizers	Rs. 2,500	Rs. 1,300	Rs. 1,200
Pesticides	Rs. 3,000	Rs. 2,500	Rs. 500
Miscellaneous	Rs. 4,000	Rs. 3,000	Rs. 1,000
Total Cost	Rs. 19,000	Rs. 16,000	Rs. 3,000

Despite a slight reduction in yield (2233 kg/acre in transplanted vs. 2040 kg/acre in DSR), the **net income** from DSR remains competitive (Rs. 32,364/acre), with a **benefit-cost ratio of 2.8**, which is higher than that of the traditional method (2.7).

Impact and Conclusion

Sri Thota Nageswar Rao's journey exemplifies how traditional knowledge when combined with scientific intervention and modern technology can transform agriculture. His adoption and promotion of direct-seeded rice and other seed drill-based practices have not only reduced cultivation costs but also encouraged sustainable agriculture in his community. Today, he continues to serve as a role model, motivating fellow farmers to embrace mechanized and climate-resilient farming practices for a better future.

VARIETAL SELECTION OF DRAGON FRUIT

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Introduction

Dragon fruit, scientifically known *Hylocereus undatus* is a climbing cactus distinguished by its unique dragon – like appearance, featuring scales or bracts on the fruit surface. This fruit is commonly known as pitaya or pitahaya in Latin America, paniniokapunahou or papipipupa in Hawii, and night- blooming cereus or strawberry pear in Southeast Asia. Grown primiarly in subtropical and tropical regions, dragon fruit is a available throughout the year and is valued for its exotic visual appeal. It juicy pulp is filled with numerous small black seeds, offering not only a visually pleasing experience but also potentially high levels of micronutrients and antioxidants (Kakade et al., 2020).

Importance of dragon fruit

The global focus on the impact of climate change and human activity on land use patterns and degradation has led to recognition of the need to utilize underutilized harsh and waste landforms for food production, particularly in the face of declining productive lands due to human interventions. In regions like the Deccan region of India, characterized by factors such as low rainfall, high temperatures, and soil constraints, there is a growing realization that horticultural crops may high temperatures, and soil constraints; there is a growing realization that horticultural crops may be more suitable for cultivation than traditional field crops. Therefore, there is an urgent imperative to identify crops, species, and varieties that can thrive in these harsh agro-ecologies. Additionally, urban consumers, increasingly health-conscious, are seeking

natural products to address common urban consumers, increasingly health-conscious, are seeking natural products to address common crops for introduction, factors such as adaptation, shelf-life, and consumer acceptance become crucial, offering opportunities for economic development in debt-ridden farming communities inhabiting drought-prone and degraded land areas. Furthermore, there's a need to diversify from traditional orchards and expand the range of fruit varieties to meet consumer demands and suit the conditions of these challenging environments. Land forms for food production, particularly in the face of declining productive lands due to human intervention.

Selection of suitable variety

In India, the available dragon fruit varieties are predominantly imported from other countries. Selecting the right variety or clone is crucial as it directly influences the fruit quality and yield. Currently, there are no officially released dragon fruit varieties or clones in India.



Red skin, white flesh



Red skin, red flesh



Red skin, purple flesh



Yellow skin, white flesh

The majority of growers in the country cultivate the red-skinned variety with white pulp (*Hylocereus undatus*), which constitutes around 93% of the cultivation. The red-skinned variety with red flesh (*Hylocereus monacanthus*) and the yellow-skinned variety with white flesh (*Hylocereus megalanthus*) are grown on a smaller scale. Our research farm at ICAR-IISWC has undertaken evaluations of *Hylocereus undatus* using horti-silviculture techniques specifically designed for rainfed agro-ecosystems.

Propagation and Nursery Management

Dragon fruit can be efficiently propagated through stem cuttings, offering a quicker and more reliable method of multiplication compared to seed-propagated plants, which may not retain desired characteristics and have a longer juvenile period. Optimal cuttings for propagation typically range from 15 to 60 cm in length, or whole segments of cladodes with consistent coloration. At the ICAR-IISWC Research Farm, it was observed that dragon fruit cuttings of larger size exhibited enhanced root and shoot growth. Careful selection of mother plants and cuttings for multiplication is crucial, as cutting size, use of rooting hormones, and rooting substrates significantly affect root initiation, number, length, and growth. Although cuttings ranging from 5 to 60 cm can root, those measuring 20-25 cm in length are preferred for planting (Kakade et al., 2019). Mature cuttings with dark green coloration are ideal for multiplication. When separating cuttings from the mother plant, make clean and slanted cuts to promote proper rooting. Treat cuttings with fungicides to prevent fungal diseases. The best time to separate cuttings from mother plants is after the fruiting season. Planting can be done in polythene bags or raised beds to ensure successful establishment.

Planting time and design

The rainy season, particularly during the monsoon (June to August), is the ideal time for planting dragon fruit. However, it can also be planted in other seasons with the provision of irrigation. Transplanting during March onwards results in transplanting shock due to higher temperatures. In which, green cladodes get bleached, while in severe cases it turns orange-brown and starts rotting. Sudden change in temperature results in such shock. So, transplanting shall be avoided during this time. If someone has to transplant during this time, he should take care while transplanting by using intercrops like pearl millet or sorghum to provide necessary shade during the harsh summer.

Dragon fruit being a climbing and epiphytic plant requires support to grow. Different trellis system can be used to establish dragon fruit orchard as per availability. In most commonly used system of “cement pole and ring” cement pole (2 m height and 4 inch width) is used and buried 30-40 cm in the ground. The concrete rectangular frame was fixed on the top of pole to allow the stems to grow downward side. Planting 3-4 plants around a pole in pits measuring 0.5 x 0.5 x 0.5 meters is recommended. These pits should be filled with topsoil, along with FYM (Farm Yard Manure) and other fertilizers. After planting the cuttings, regular watering in the



basin around the plants is necessary to promote proper rooting. Planting can be done at various spacing options, such as 2.5×2 meters, 3×1.5 meters, 3×3 meters, and 4×3 meters, depending on the specific situation. It is important to avoid planting dragon fruit at spacing below the optimum, as it can hinder harvesting and other intercultural operations. For sustaining the survival and growth of dragon fruit in-situ soil moisture conservation (half-moon terrace) structure was made for each plant.





YEAST PIGMENTS FOR FOOD AND FEED APPLICATIONS

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Abstract

Yeast-derived pigments have emerged as a promising alternative to synthetic colorants in the food and feed industries. These natural pigments, including carotenoids, melanins, and anthraquinones, offer various functional benefits such as antioxidant activity, UV protection, and antimicrobial properties. As consumer preferences shift toward natural and sustainable ingredients, yeast pigments have gained significant attention due to their high stability and bioavailability. This review explores the types of yeast pigments, their biosynthetic pathways, functional properties, and industrial applications. Additionally, it discusses challenges related to production costs, regulatory approvals, and optimization strategies for large-scale implementation. Future advancements in fermentation technology and metabolic engineering hold great potential for expanding the use of yeast pigments in food and feed industries.

Introduction

The global food and feed industries are experiencing a paradigm shift towards natural and sustainable ingredients, driven by increasing consumer awareness and regulatory pressures against synthetic additives. Colorants play a crucial role in food and feed formulations, influencing consumer perception and product appeal. While synthetic dyes have traditionally dominated the market, concerns over their potential health risks have accelerated the search for natural alternatives. Among these, yeast-derived pigments have garnered significant interest due to their safety, functionality, and environmental sustainability.

Yeasts, particularly species such as *Rhodotorula*, *Phaffia rhodozyma* (now *Xanthophyllomyces dendrorhous*), and *Sporidiobolus*, are known for their ability to produce carotenoids, which impart yellow, orange, and red hues. Additionally, yeasts like *Cryptococcus* and *Yarrowia lipolytica* synthesize melanins, which offer UV protection and antioxidative benefits. Furthermore, anthraquinones and other phenolic pigments from certain yeast strains exhibit antimicrobial properties that enhance food preservation.

In recent years, biotechnological advancements have enabled enhanced pigment production through genetic engineering and optimized fermentation techniques. However, challenges such as high production costs, limited regulatory approvals, and the need for scalable production methods remain. This review aims to provide a comprehensive overview of yeast pigments, covering their classification, biosynthesis, functional properties, and industrial applications. Additionally, it addresses key challenges and future directions for their utilization in food and feed industries (Poorniammal et al 2021).

Types of Yeast Pigments

Yeast pigments are primarily classified into three major categories:

1. Carotenoids

Carotenoids are lipid-soluble pigments that provide yellow, orange, and red hues. Yeasts such as *Rhodotorula*, *Phaffia rhodozyma* (now *Xanthophyllomyces dendrorhous*), and *Sporidiobolus* spp. are well-known producers of carotenoids like:

- **β -carotene** (precursor to vitamin A, antioxidant properties)
- **Astaxanthin** (strong antioxidant, used in aquaculture and poultry feed)
- **Torularhodin and torulene** (unique yeast-derived carotenoids with potential health benefits)

2. Melanins

Melanins are high-molecular-weight, dark-colored pigments with strong antioxidant and UV-protective properties. *Cryptococcus* and *Yarrowia lipolytica* produce melanin via the oxidation of phenolic compounds. These pigments show promise as natural food colorants and protectants in feed formulations.

3. Anthraquinones and Other Phenolic Pigments

Yeasts such as *Monascus* spp. produce anthraquinones, which contribute to reddish hues. These pigments have antimicrobial and antioxidant functions, enhancing food stability and quality.

Biosynthesis of Yeast Pigments

1. Carotenoid Biosynthesis

Carotenoid biosynthesis follows the mevalonate (MVA) pathway, leading to the production of isoprenoid precursors. Key enzymes involved include:

- **Geranylgeranyl pyrophosphate synthase (GGPS)** – precursor formation
- **Phytoene synthase (CrtYB)** – initial carotenoid synthesis
- **Phytoene desaturase (CrtI)** – formation of colored carotenoids

2. Melanin Biosynthesis

Melanin synthesis involves the polymerization of phenolic compounds through oxidative pathways mediated by:

- **Tyrosinase** – converts tyrosine to melanin precursors
- **Laccase** – contributes to melanin polymerization

3. Anthraquinone Biosynthesis

Yeasts capable of producing anthraquinones use polyketide synthase (PKS) enzymes to generate complex aromatic pigments with strong bioactivities.

Functional Properties of Yeast Pigments

1. Antioxidant Activity

Carotenoids and melanins exhibit strong free-radical scavenging properties, reducing oxidative stress in food products and feed formulations. ★ ★ ★ ★

2. UV Protection

Melanins absorb UV radiation, making them useful as natural sun-protectant additives in food packaging and animal feed.

3. Antimicrobial Effects

Certain yeast pigments, particularly anthraquinones, show antimicrobial properties against foodborne pathogens, enhancing food safety and shelf life.

Applications in Food and Feed Industries

1. Food Industry

- **Natural Food Colorants:** Carotenoids from *Rhodotorula* spp. are used in beverages, dairy, and confectionery products.
- **Functional Foods:** Astaxanthin-enriched yeast extracts are incorporated into nutraceuticals for their health benefits.

- **Meat Alternatives:** Yeast-derived pigments enhance the color of plant-based meat substitutes.

2. Feed Industry

- **Aquaculture Feed:** Astaxanthin from *Phaffia rhodozyma* is widely used to enhance the pigmentation of salmon and shrimp.
- **Poultry Feed:** Carotenoids improve egg yolk coloration and poultry skin pigmentation.
- **Livestock Nutrition:** Antioxidant-rich yeast pigments contribute to animal health by reducing oxidative stress.

Challenges and Future Prospects

Despite their potential, yeast pigments face challenges related to:

- **Production Costs:** High costs of fermentation and extraction limit large-scale application.
- **Regulatory Approval:** Some yeast pigments require additional safety assessments.
- **Optimization of Yield:** Genetic and metabolic engineering can enhance pigment production for industrial use.

Future research should focus on cost-effective production strategies, novel yeast strains, and expanding regulatory approvals to facilitate broader adoption in food and feed sectors.

Conclusion

Yeast-derived pigments represent a sustainable, natural alternative to synthetic colorants in the food and feed industries. Their diverse bioactivities, coupled with growing consumer demand for natural additives, make them promising candidates for widespread application. With advancements in fermentation technology and biotechnology, yeast pigments are poised to play a crucial role in the future of food and feed industries.

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BENEFICIAL INDIGENOUS MICROORGANISMS AND SOIL HEALTH REJUVENATION IN NATURAL FARMING

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Abstract

Beneficial Indigenous Microorganisms (BIMs), also called Indigenous Microorganisms (IMOs), are essential to sustainable agricultural practices, especially in natural farming systems. These naturally occurring microbial communities, including bacteria such as *Azotobacter*, *Pseudomonas*, and *Streptomyces*, as well as fungi like *Trichoderma* and *Aspergillus*, contribute significantly to enhancing soil health, promoting robust plant growth, and increasing crop yields, all without the use of synthetic fertilizers or pesticides. BIMs are instrumental in key soil processes such as nitrogen fixation, organic matter decomposition, and nutrient cycling, collectively improving soil structure and fertility. Originating in South Korea, BIM technology has been effectively implemented in over 30 countries, showcasing its adaptability and efficacy across diverse agricultural landscapes. This paper explores the genesis, development, and widespread application of BIM technology, emphasizing its role in fostering sustainable agricultural ecosystems. Additionally, the study delves into the methodologies for the mass production of BIMs and their integration into composting and other soil enhancement practices, highlighting their critical role in promoting long-term agricultural productivity and environmental stewardship. By incorporating BIMs into farming practices, there is significant



potential to achieve sustainable and eco-friendly agricultural systems that support both productivity and ecological balance.

Keywords: Beneficial Indigenous Microorganisms, Sustainable agriculture, Soil fertility, Natural farming

Introduction

Natural farming is an environmentally friendly and sustainable agricultural practice that relies on natural inputs and processes to improve soil quality, boost crop production, and enhance the well-being of farmers. It focuses on biodiversity, soil regeneration, and water conservation. This method works in harmony with nature, avoiding synthetic inputs, and promotes soil health through techniques like cover cropping, mulching, and utilizing indigenous beneficial microorganisms. By prioritizing local resources, biodiversity, and symbiotic relationships, natural farming supports sustainability and long-term ecological balance. This approach improves soil fertility, conserves water, and minimizes ecological impact, contributing to the long-term viability of agriculture. Natural farming using Beneficial Indigenous Microorganisms (BIM or IMO) is a distinctive organic farming technique that has been successfully adopted in over 30 countries, both in home gardens and on a commercial scale. Significant improvements in soil structure and plant health have been observed with the use of indigenous microorganisms in natural farming, as the soil regains its loaminess, tilth, and structure, attracting large numbers of earthworms. Indigenous microorganism-based technology is among the most crucial technologies, as these microbes naturally inhabit the soil and have the ability to biodegrade, bioleach, biocompost, fix nitrogen, enhance soil fertility, and produce plant growth hormones. Additionally, these microorganisms represent a diverse group of naturally occurring, yet often unknown or poorly defined, microbes that interact positively with soil and plants, providing beneficial effects that are often unpredictable.

Beneficial Indigenous Microorganisms are used as a fermented microbial solution with various applications in farming, playing a vital role in natural farming. They are effective in speeding up the decomposition of organic materials and can be used as organic fertilizers for plants. These microbes are known to promote plant growth by producing phytohormones such as gibberellins, cytokinins, auxins, and inhibitors. IMO technology has been widely adopted in organic farming across more than 30 countries, proving to be a successful method. Genesis of IMO Technology The agricultural scientist Padma Shri Subhash Palekar is the founder of Zero

Budget Natural Farming (ZBNF) concepts. In India, Subhash Palekar implemented zero budget spiritual holistic farming in Andhra Pradesh, Gujarat, and Himachal Pradesh, encompassing Bijamirth, Jeevamrith, Whapasa, and Acchadana as four major pillars of soil fermenting farmers' friend. In Tamil Nadu, IMO-based technology was highlighted and spread by the agricultural graduate, organic scientist, and Saint Dr. G. Nammalvar, who initiated the organic farming movement and formed the organic farmers' federation in Tamil Nadu. He founded Vanagam, a non-governmental organization in Kadavur, Karur district, Tamil Nadu. IMO-based technology was actually developed and introduced by Dr. Chou Hankyu in the 1960s. He applied this technology in natural farming and observed remarkable improvements in soil structure and plant health, as the soil, after IMO application, restored its loaminess, tilth, and structure, attracting large numbers of earthworms, often referred to as the farmer's natural allies.

Keliikuli et al. (2019) highlighted that natural farming using Indigenous Microorganism (IMO) technology is a unique method in organic agriculture, adopted in over 30 countries for both home gardens and commercial farming. This approach was traditionally utilized by farmers in countries such as Korea, Japan, China, Malaysia, Thailand, Congo, Tanzania, Vietnam, the Philippines, and Mongolia. Dr. Chou Hankyu developed this eco-friendly farming technique, which promotes sustainable agriculture and enhances crop production through extensive field experiments. He refined these practices and trained over 18,000 individuals at the Janong Natural Farming Institute in South Korea. Dr. Hoon Park, during his missionary work in South Korea, observed the effectiveness of IMO technology in eliminating unpleasant odors in commercial piggeries and poultry farms. Subsequently, he introduced these natural farming methods to Hawaii, demonstrating their simplicity, practicality, reliability, and cost-effectiveness while being environmentally beneficial.



Duck farming in paddy cultivation

BIMs' and EMs': Breakthrough in sustenance farming

Beneficial Indigenous Microorganisms (BIM), also referred to as Indigenous Microorganisms (IMO), constitute a naturally occurring microbial consortium present on the surfaces of both internal and external living organisms. These microorganisms possess the ability to produce plant growth-promoting hormones and are involved in processes such as nitrogen fixation, biodegradation, bioleaching, and composting. IMOs are physiologically compatible, coexisting and complementing each other. The term "indigenous microorganisms" generally denotes specific mixed cultures of well-recognized, beneficial microorganisms that are effectively utilized as microbial inoculants. These microorganisms may naturally occur in soil or be introduced as inoculants to enhance soil quality, boost crop productivity, and promote ecologically and economically sustainable practices. While BIMs occur naturally, Effective Microorganisms (EMs) are human-created; otherwise, there are relatively few differences between the two. Native Microorganisms represent an innovative technology. These organisms inhabit the soil and perform remarkable functions, including nitrogen fixation, biodegradation, bioleaching, composting, and enhancing soil fertility. They also contribute to the production of plant growth hormones. This complex assemblage of living microbes interacts positively with soils and plants, often remaining unnoticed or poorly understood, yet yielding unexpected beneficial outcomes.

Effective microorganisms, or EMs, are a variety of microorganisms that were artificially generated in a laboratory. On the other hand, indigenous microorganisms are a group of beneficial microbes that are endemic to the location and are hence called indigenous. Native microorganisms are a community of beneficial bacteria that coexist harmoniously with the rest of nature as opposed to a single culture of microorganisms which provide beneficial effects on health. IMOs offer the perfect conditions for maintaining and improving the soil's fauna, flora, and other microbes, all of which enhance the quality of life for higher plants and animals, including humans. Native microorganisms are a type of naturally occurring microbial consortium that live in the soil and on the outermost layers of all living species, inside as well as outside. They can be used as biodegraders, nitrogen fixers, soil fertility enhancers, phosphate solubilizers, and growth promoters for crops. Without these bacteria, life on this vibrant planet will be unpleasant and is vital to the survival of the human species. For this reason, native

microorganisms are used in environmental rehabilitation and protection to convert trash and useless materials into useful resources.

EM is a commercial mixture of microorganisms such as photosynthesizing bacteria, *Actinomycetes*, lactic acid bacteria, yeasts, and fermenting fungi (*Aspergillus* and *Penicillium*) that are grown as consortium. EM consist of common and food-grade aerobic and anaerobic micro-organisms: Photosynthetic bacteria, *Lactobacillus*, *Streptomyces*, *Actinomycetes*, Yeast, etc., Earlier study confirmed that *Aspergillus flavipes*, *Penicillium*, *Chrysogenum*, *Cochliolous speifer*, *Rhizopus oryzae* and *Trichoderma viride* were found effective in agro waste decomposition. The microbiological composition of the EM concentrate is as follows:

- *Streptomyces albus* and *S. griseus*
- *Propionibacterium freudenreichii*
- *Streptococcus lactis*
- *Lactobacillus* sp.
- *Rhodopseudomonas* sp.
- *Aspergillus oryzae*
- *Mucor hiemalis*
- *Saccharomyces cerevisiae*
- *Candida utilis*

Indigenous Method of fruit/vegetable EM preparation

EM formulation prepared from fruit wastes-based EM was superior in converting sugarcane trash to compost. EM converted sugarcane trash into compost in 60 days. The EM-F was rich in lactic acid bacteria (*Lactobacillus*), yeast (*Saccharomyces*), *Actinomycetes* (*Streptomyces*), Fungi (*Aspergillus*). Jaggery syrup solution was prepared by dissolving 500 g jaggery in 500 ml of water. The fruit wastes of pumpkin and papaya were made into pulp fruit pulp and jaggery solution is then mixed in 4 liters of water in an earthen pot. The contents are mixed thoroughly. Rhizosphere soil (500 g) from fertile sugarcane crop field was added into earthen pot. The pot was covered with a white cloth lid and kept in a shaded area for 10 days. Each day, the lid was removed, and the contents were stirred thoroughly with a sterilized glass rod to enhance the growth of the EM (Gayathry and Ravichandran, 2020).

Indigenous microorganisms are crucial in defending the normal host from potential disease-causing microorganisms. They compete for vital nutrients and cell receptors with pathogens by creating bacteriocins and other inhibitory substances, which prevents pathogens from colonizing the environment. They make up a crucial part of global biodiversity. These microorganisms enhance the nutrients accessible to host plants and boost water retention, ensuring plants have a continual water supply. Enhancing aeration to plant roots aids in efficient gas exchange and helps in soil erosion prevention. Depending on the locations where items are gathered, the methods of collecting and isolating them differ due to the potential variation in procedures. Various environmental factors influence the potential for biodegradation, encompassing physical and chemical elements like temperature, pH, organic matter, oxygen levels, nutrient availability, and more. Indigenous microorganisms were separated and tested at each composting phase for their capacity to break down phosphate and generate indole-3-acetic acid.

Microbiological phenomenon in agricultural practice

The idea of BIMs has mainly been applied to natural farming, which uses living microbes that are easily and frequently available in the area to create rich soils and increased yields without the need of pesticides or herbicides. It has been reported that using BIMs in natural farming has had remarkable effects on plant health and soil structure. BIMs can be mass multiplied in poultry, piggery units, deep litter forests, composting pits, farm yard manure pits, cow shed etc. The pigs' excrement is so odourless, clean and dry, that you literally do not even have to clean it out. Microorganisms are found all over the soil, where they interact with plants and other soil organisms to mediate a variety nutrient cycling processes and play a critical role in the in nutrient cycling, and where they mediate various processes through their interactions with plants and other soil organisms.

In another research report of Nghia (2020) highlighted the isolation and identification of BIM from different cropping ecosystem such as Bamboo, paddy, Banana, field three different crop rotation such as Corn, Watermelon, Courgette, Shallot, Lettuce, Grassland, Maize, vegetables, Oranges, Grapefruit and Guava. In all the sites, the number of bacteria was significantly more than fungi and actinomycetes.

Aggregates of soil particles retain water and air, which in turn makes a favourable environment without artificial chemical fertilizers and pesticides as inputs, higher-quality crops

and livestock are guaranteed. Because microorganisms naturally exist in the soil and interact with plants, their role is advantageous in increasing the amount of macro and micronutrients. It is hard to overestimate the significance of microorganisms (fungi, bacteria, actinomycetes, and yeasts); however, because conventional agricultural systems primarily rely on non-sustainable energy, fertilizer, and pesticide inputs, their existence and activities are generally overlooked. Studies were conducted by Sunitha et al. (2023a) that the application of *jeevamrith* and *bijamrith* in sorghum and cowpea intercropping systems recorded a greater number of total microbial count in soil and was found to increase during the vegetative stage of the crop.

Indigenous microorganisms, encompassing photosynthetic bacteria, lactic acid bacteria, and fermenting fungi such as *Aspergillus*, *Penicillium*, and *Trichoderma*, contribute significantly to plant growth and development. These microorganisms expedite the decomposition of organic matter, mitigate unpleasant odors, and inhibit infestations by harmful insects and maggots. Arbuscular Mycorrhizae (AM) fungi and phosphorus-solubilizing bacteria, known as mycorrhiza helper bacteria, facilitate enhanced plant nutrient absorption. Furthermore, plant growth-promoting rhizobacteria have the potential to augment mycorrhizal fungal activity and establishment. AM fungi are particularly instrumental in enhancing plant growth and nutrient absorption, especially within the context of organic agriculture. However, during ecosystem restoration efforts in degraded areas, AM fungi inevitably interact with native microorganisms (George and Ray, 2023). The "Rhizolive consortium," comprising indigenous mycorrhizal fungi and plant growth-promoting rhizobacteria (PGPR), bolsters plant growth and development by employing strategies and mechanisms that ensure robust production and confer protection against various pathogens, notably the root wilt pathogen *Verticillium* sp. AM fungi, in conjunction with differentially expressed genes (DEGs) and mycorrhizae helper bacteria, can enhance plant growth, increase biomass, and augment nitrogen (N) and phosphorus (P) accumulation. They also reduce the N/P ratio and improve nutrient absorption. Nevertheless, indigenous microorganisms may counteract these AM-induced benefits by regulating genes associated with phosphorus transport and nitrogen assimilation, thereby influencing plant growth and nutrient uptake (Ren et al., 2022).

Mass multiplication of Beneficial Indigenous Microorganisms

The methodology of BIM multiplication is culturing indigenous microbes in a simple wooden box of rice, mixed with country sugar and stored in an earthenware, further propagated

on rice bran or wheat mill run, mixed with clay soil/ant hill soil. Again, they are then mixed with compost, added to potting soil, or spread on beds before planting. The entire process takes three to four weeks. Other inputs and sprays can also be made from fermented plant juices, made from the tips of growing plants mixed with brown sugar.

Cultivation of indigenous microorganisms from soil and animal excrements

The benefits of using the natural farming inputs for soil health management offers lower costs to the farmer, more desirable crops, stronger, healthier and more nutritious plants, higher yield, better quality, Farmer friendly and zero waste emission. Some examples of indigenous microbial organic formulations and concoction prepared from fish wastes, poultry litter, cow, goat urine and dung are fish amino acid, poultry litter, farm yard manure, *Ghanajeevamrith*, *jeevamrith*, *bijamrith*, *panchakavya*, *dasakavya*, *Aavoottam*. Clearly it makes sense to utilize these resources, particularly through direct agronomic management, which would be of the greatest benefit to farmers.



Ghanajeevamrith from desi cow dung: organic biomanure

Water soluble Calcium rich IMOs

Water-soluble calcium made from eggshells or called as bio-albumix, fish amino acid made from fish waste, lactic acid bacteria mass multiplied from cow ghee, buttermilk: coconut milk formulation (*Themoor karaisal*) and insect attractants made from rice wine, vegetable sugary rich organic wastes such as the black soldier fly, basically used for protein rich composting process. Water-soluble calcium phosphate, derived from animal bones, is used based

on the plant's nutritional and growth stages. Fish amino acids are made by fermenting fresh, deboned fish waste mixed with brown sugar in a container for several months.

Traditional indigenous microbial organic formulations

Microbial community is crucial in breaking down organic materials and generating compost, it is essential to investigate the variety of microorganisms present throughout the composting or concoction processes. Some examples of indigenous microbial organic formulations and concoction prepared from poultry litter, cow, goat urine and dung are fish amino acid, poultry litter, farm yard manure are *Amritpani*, *bijamrith*, *ghanajeevamrith*, *jeevamrith*, *panchakavya*, *dasakavya*, *Aavottam*. The benefits of using the natural farming inputs for soil health management offers lower costs to the farmer, more desirable crops, stronger, healthier and more nutritious plants, higher yield, better quality, farmer friendly and zero waste emission. In India, Yadav et al. (2020) identified fungal species like *Cunninghamella* sp., *Aspergillus* sp. and *Rhizopus* sp., and the bacterial colonies *Paenibacillus amylolyticus* which posses biological nitrogen fixation and phosphorous solubilising ability, *Enterococcus casseliflavus* a potential probiotic which have beneficial effect on gut health and disease resistance of farm animals.

Gas chromatography-mass spectrometry (GC-MS) analysis of *bijamrith*, derived from Gir cow dung and urine, identified 40 distinct compounds within the bioformulation. Notably, the fatty acid 9-octadecenoic acid (Z)- and the ester compound 2,3-dihydroxypropyl were present in higher concentrations and are known for their antifungal, antibacterial, and anti-inflammatory properties. Additional biologically active compounds detected include antioxidants, plant growth hormones, and nematicidal agents, which contribute to plant defense mechanisms and health improvement (Sunitha et al., 2023b). Sunitha et al. (2024) developed a crop biostimulant, *jeevamrith*, also from Gir cow dung and urine, which was found to contain hydrocinnamic acid and other plant growth-promoting fatty acids and amino acids. In traditional formulations, a specific indigenous preparation rich in potassium (92 mg/kg) known as 'Goat aavottam' is reported from the Erode district. Goat and sheep excrements, characterized by their hardness and low solubility in water, can be enhanced with indigenous microorganisms (IMOs) to produce enriched goat manure. This enriched manure is applied as a 2% foliar spray to promote plant growth, enhancing branching, leafing, flowering, and fruiting in various crops (Nandhini and Somasundaram, 2023).

Conclusion

It is clearly evident that IMO's are fermentation farmers in natural farming and the potential microorganisms can be selected for development of biofertilizer for organic farming. The modified "Natural Farming" composting method is a simple, cheap, and fast method used to produce EFB compost that contains beneficial microorganisms with the potential to be developed into biofertilizer. Combination of microbial strains could be a good multifunctional biofertilizer for sustainable agriculture. Agro-waste management and enhancement of biodiversity are the approaches towards sustainability. A significant amount of creative research is still required to use IMO's in a sustainable environment.

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THE PULSE OF LIFE SCIENCE RESEARCH

Article ID: AG-VO5-I05-82

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Abstract

The "Pulse of Life Science Research" captures the unprecedented acceleration in biological and biomedical discovery. This explores the current dynamism and critical trends shaping life science research. We delve into the convergence of cutting-edge technologies like AI and CRISPR, the increasing emphasis on interdisciplinary collaboration, and the rapid translation of foundational discoveries into clinical applications and biotechnological innovations. The "pulse" signifies not only the accelerating pace of discovery but also the vital impact this research has on addressing global health challenges and enhancing human well-being. This examines the key drivers behind this rapid progress, including advancements in genomics, proteomics, and computational biology, and their profound influence on understanding disease mechanisms and developing novel therapies. We highlight the transformative impact of this research on medicine, agriculture, and environmental sustainability, emphasizing its role as a vital force in shaping the future. This provides an overview of the defining innovations currently driving life science research. We examine how breakthroughs in gene editing, single-cell analysis, and advanced imaging techniques are revolutionizing our ability to probe biological systems with unprecedented resolution. The "pulse" reflects the constant influx of new methodologies and insights, fostering a vibrant ecosystem of discovery that holds immense promise for personalized medicine, drug development, and a deeper understanding of life itself.

Introduction

The life sciences sector is experiencing a period of unprecedented dynamism, driven by rapid technological advancements, evolving healthcare needs, and a surge in interdisciplinary

collaboration. This introduction explores "The Pulse of Life Science Research," highlighting the key trends, breakthroughs, and future directions that are shaping this vital field.

Technological Revolution: Technologies like Artificial Intelligence (AI) and Machine Learning (ML) are transforming every aspect of life sciences, from accelerating drug discovery and development to enhancing diagnostics and personalized medicine. AI can analyze vast datasets, identify potential drug candidates, and streamline research processes, significantly reducing the time and cost involved. Similarly, advancements in biotechnology and genomics, including next-generation sequencing (NGS) and gene editing technologies like CRISPR-Cas9, are providing unprecedented insights into biological systems and enabling precise interventions.

Personalized Medicine: Driven by advancements in genetic research and a deeper understanding of individual biological variations, personalized medicine is gaining significant traction. This approach aims to tailor treatments and preventative strategies to each patient's unique genetic makeup, lifestyle, and environment, leading to more effective and targeted therapies.

Digital Health and Patient-Centric Care: The integration of digital health technologies, including wearable devices, telehealth platforms, and digital therapeutics, is making healthcare more accessible, efficient, and patient-centric. These tools facilitate remote monitoring, enable participation in clinical trials from home, and empower individuals to take a more active role in managing their health.

Sustainability: The life sciences industry is increasingly focusing on sustainability, adopting greener chemistry practices in pharmaceutical manufacturing, integrating carbon footprint calculators into supply chains, and investing in eco-friendly processes.

Data Analytics and Big Data: The "omics" fields (genomics, proteomics, metabolomics, etc.) are generating enormous amounts of complex biological data. Advanced data analytics and big data tools are crucial for interpreting these datasets, leading to groundbreaking discoveries in areas like cancer genomics, immunotherapy, and vaccine development.

Automation and Robotics: Labs are becoming increasingly automated with the integration of robotics and AI models. This streamlines operations, boosts efficiency, and frees up scientists to focus on more complex research questions.

Recent Breakthroughs and Impact:

The past few years have witnessed remarkable breakthroughs, including:

- **CRISPR-Cas9 Gene Editing:** This revolutionary technology continues to unlock possibilities for precisely altering DNA, offering immense potential for treating genetic disorders and developing new therapeutic strategies.
- **RNA Medicine:** While mRNA vaccines gained prominence during the COVID-19 pandemic, the broader application of RNA technology is still in its early stages, promising new avenues for drug development and disease treatment.
- **Advances in AI for Drug Discovery:** AI-driven platforms are dramatically accelerating the identification of drug candidates and optimizing drug development pipelines, leading to faster development of new treatments.
- **Improved Diagnostics:** Innovation in life sciences has led to more accurate and precise diagnostic tools, enabling earlier detection and better management of diseases.

Future Directions:

Looking ahead, the life sciences industry is poised for continued transformation. Key areas of focus will include:

- **Further integration of AI and machine learning:** Expect deeper integration of AI across all stages of research, development, and healthcare delivery.
- **Expansion of personalized and preventive healthcare:** Tailored treatments and proactive health management will become more prevalent.
- **Advanced biomanufacturing and 3D bioprinting:** The ability to engineer tissues and organs will continue to advance, offering solutions for regenerative medicine and drug testing.
- **Enhanced global collaboration and data sharing:** Secure and efficient sharing of knowledge and resources will be critical for addressing global health challenges.
- **Addressing the funding landscape:** Securing adequate funding remains crucial for life science startups and established companies alike, with increasing emphasis on strategic partnerships, non-dilutive financing, and a focus on projects with clear value propositions and shorter timelines to market.
- "The Pulse of Life Science Research" is characterized by relentless innovation, interdisciplinary convergence, and a profound commitment to improving human health

and well-being. As technology continues to advance and our understanding of biology deepens, the impact of this dynamic field will only continue to grow.

Conclusion

The "Pulse of Life Science Research" beats with an accelerating rhythm, driven by a confluence of technological breakthroughs, evolving healthcare demands, and a steadfast commitment to unraveling the complexities of biological systems. As we have explored, the landscape is characterized by the transformative power of AI and machine learning, the promise of personalized medicine, the increasing adoption of digital health solutions, and a growing emphasis on sustainability.

The recent past has witnessed a remarkable series of achievements, from the revolutionary potential of CRISPR gene editing to the widespread impact of mRNA technology and the AI-driven acceleration of drug discovery. These breakthroughs are not isolated events but rather interconnected threads in a rapidly expanding tapestry of scientific understanding, each building upon the last to push the boundaries of what is possible. Looking ahead, the life sciences are poised for even more profound transformations. The deeper integration of AI, the expansion of personalized and preventive healthcare, and the continued advancements in biomanufacturing and regenerative medicine will fundamentally reshape how we approach health and disease.

This dynamic field will increasingly rely on enhanced global collaboration and secure data sharing to tackle the most pressing health challenges facing humanity. Ultimately, the pulse of life science research reflects a vibrant and indispensable sector at the forefront of innovation. Its relentless pursuit of knowledge, coupled with its capacity to translate scientific discovery into tangible solutions, ensures its pivotal role in shaping a healthier, more sustainable future for all.

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CORAL REEF DEOXYGENATION AND ITS EFFECT ON REEF - BUILDING SPECIES

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Abstract

Coral reef deoxygenation, driven by ocean warming and nutrient pollution, is emerging as a major threat alongside acidification and thermal stress. Declining dissolved oxygen levels disrupt the delicate balance of reef ecosystems, leading to increased physiological stress, reduced photosynthetic efficiency, and heightened mortality in sensitive reef-building coral species. Species such as *Acropora cervicornis* and *Orbicella faveolata* are particularly vulnerable, with hypoxic events causing rapid declines in coral health and recruitment. These events can shift community composition, reduce biodiversity, and undermine reef resilience. Recent studies highlight the urgent need for comprehensive monitoring of oxygen levels and targeted conservation strategies to protect susceptible coral populations. Addressing both global climate change and local nutrient runoff is essential to mitigate the impacts of deoxygenation and preserve the ecological integrity of coral reefs in a changing ocean.

Keywords:

Coral reef deoxygenation, hypoxia, reef-building corals, coral mortality, ecosystem resilience

Introduction

Coral reefs are among the most biodiverse ecosystems on Earth, but they are increasingly threatened by a range of climate change-related stressors. While ocean warming and acidification

have long been recognized as major threats, ocean deoxygenation - declining levels of dissolved oxygen in seawater—has recently emerged as a third major challenge for coral reef survival. Deoxygenation is driven by ocean warming, which reduces oxygen solubility, and by nutrient pollution that fuels algal and microbial blooms, further depleting oxygen. This phenomenon is now recognized as a widespread and growing risk for coral reefs globally, with profound implications for reef-building species and the ecosystems they support (Mallon *et al.*, 2025; Hughes *et al.*, 2023).

Causes and Patterns of Coral Reef Deoxygenation

Oxygen concentrations on coral reefs naturally fluctuate on a daily cycle, peaking during daylight hours due to photosynthesis and dropping at night as all reef organisms respire. However, recent studies show that these **natural cycles** are being exacerbated by climate change and human activities. Warmer waters hold less dissolved oxygen, and increased nutrient runoff from land can trigger algal blooms that consume oxygen as they decompose. These processes have led to more frequent and severe hypoxic events - periods when oxygen levels fall below the threshold needed to support healthy coral metabolism (Mallon *et al.*, 2025; Scripps Institution of Oceanography, 2023).

A comprehensive global survey found that 84% of reefs already experience weak hypoxia, while 13% suffer severe hypoxia. Projections indicate that, under high - emission scenarios, nearly all coral reefs may face regular, **prolonged** hypoxic events by the end of the century (Hughes *et al.*, 2023).

Effects on Reef-Building Coral Species

Reef-building corals, such as *Acropora cervicornis* and *Orbicella faveolata* (Fig. 1) , are particularly sensitive to oxygen fluctuations. Corals need oxygen for respiration, growth, and the maintenance of their symbiotic relationship with photosynthetic algae (zooxanthellae).



Acropora cervicornis



Orbicella faveolata

Fig. 1 Reef building coral species

When oxygen levels drop below species-specific thresholds, corals experience physiological stress, reduced photosynthetic efficiency, bleaching, and increased mortality (Nelson & Altieri, 2019; Hughes *et al.*, 2023).

Experimental studies have demonstrated that persistent low oxygen (as low as ~1.0 mg/L) leads to significant declines in coral photophysiology and survival. Juvenile corals, which lack fully developed symbiotic algae, are especially vulnerable, as they rely almost entirely on respiration for energy. Even brief hypoxic events can result in mass mortality of coral recruits, undermining reef regeneration and resilience (Mallon *et al.*, 2025; Speare *et al.*, 2021).

Species-Specific Responses and Community Impacts

Not all coral species respond to deoxygenation in the same way. Some, like *Acropora cervicornis*, show higher sensitivity to hypoxia, while others may possess greater tolerance. These differences are influenced by species-specific physiology, genetic variation, and previous exposure to fluctuating oxygen conditions (Speare *et al.*, 2021; Nelson & Altieri, 2019). Severe or repeated hypoxic events can shift coral community composition, favoring more tolerant species and leading to declines in ecosystem diversity and function. In extreme cases, entire coral communities can be decimated within days, with cascading effects on reef-associated fish and invertebrates that depend on corals for habitat and food (Mallon *et al.*, 2025; Hughes *et al.*, 2023).

Conservation and Research Implications ★★☆☆

The increasing frequency and severity of deoxygenation events underscore the need for targeted conservation and monitoring efforts. Many reef monitoring programs have not historically included dissolved oxygen measurements, but this is changing as the importance of oxygen for coral health becomes clearer. Understanding species-specific oxygen thresholds and responses will be critical for developing strategies to protect vulnerable reefs and guide restoration projects (Scripps Institution of Oceanography, 2023; Mallon *et al.*, 2025). Mitigating deoxygenation will require both global action to reduce greenhouse gas emissions and local management to control nutrient pollution. Enhanced monitoring, research on coral physiology, and the development of hypoxia-tolerant coral strains may all play a role in sustaining reef ecosystems in a changing ocean.



Conclusion

Coral reef deoxygenation is an urgent and underappreciated threat to the world's reefs and their foundational species. As hypoxic events become more frequent and severe, understanding and addressing the physiological limits of reef-building corals is essential for their conservation and the preservation of reef biodiversity.

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ORGANIC CONCOCTION IN NATURAL FARMING

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Introduction

Organic formulations derived from cow excrement and urine are promoted as a natural agriculture alternative for soil and plant nutrition, resulting in lower production costs and higher quality products and yields without the use of chemical fertilisers and pesticides. Using cow-based products enhances soil health, increases agricultural productivity, and reduces reliance on chemical fertilisers. Adding 1% organic matter can enhance crop production by around 12%.

1.Fermented Fruit Juice(FFJ)

Fermented fruit juice is an organic fertiliser made from banana, watermelon, papaya, apple, pineapple, or grape. Papaya, watermelon, and bananas contain unique characteristics that can enhance plant strength and health. Bananas are high in potassium and promote fruiting, while papaya and watermelon have high levels of chlorophyll and chromoplasts. Fermented fruit juice's inherent enzymes breakdown chlorophyll quickly, allowing plants to absorb it more effectively.

Preparation

- 1.Take banana / Papaya /Grapes
- 2.Take 1 kg of given fruits and cut into small pieces.
- 3.Add 1 kg of jaggery and mix it.
- 4.Mixed the banana and Jaggery store in a jar.

5. Within a week the FFJ is ready.

FFJ that has been diluted in 1:1000 ratio in water.

2. Beejamrit

Beejamrit is an organic pesticide used for seed treatment of several crops, including rice, wheat, maize, vegetables, and fruits. It can also be used to treat saplings of various fruits, including mango, banana, litchi, apple, peach, and pear, prior to transplantation. Beejamrit prevents fungus infections in young growing roots and protects saplings from illnesses following the wet season. Beejamrit enhances soil quality by stimulating microorganisms and facilitating plant uptake of micronutrients.

Preparation

1. Cover 1.25 kg of cow dung with fine cotton cloth and soak it in 5 litres of water for 12 hours.
2. Put 12 g of lime in a small bucket with 250 ml of water and leave it for 12 hours.
3. Remove cow dung covered in cotton garments and squeeze all of the liquid out.
4. Combine the lime solution with the liquid that was squeezed, then add a handful of soil and give it a good mix.

3. Themore Karaisal

It is used to enhance the plant growth, repels insects and is resistant to pathogen.

Preparation

1. Take 500 ml of buttermilk (fermented for 5 days) and 500 mL of fresh coconut milk.
2. Combine them together and let them ferment for four days.
3. Keep it in sunshine to speed up and increase the fermentation process.

4. Herbal kunapajala

Herbal kunapajala has a greater concentration of macro and micronutrients and increases soil fertility. Plants are able to absorb minerals more easily because of the soil's greater availability of them, especially nitrogen and magnesium.

Preparation

1. Take 20 kilograms of cow dung and 20 litres of cow urine were placed within a 200-liter plastic drum.

2. Fill a plastic barrel with two kilogrammes of sprouted urd, two kilogrammes of mustard cake, and two kilogrammes of crushed jaggery. After that, 20 litres of water were added to make sure the ingredients were well combined.

3. Then, 20 kg of fresh nettle plants were placed to the drum after being weighed and finely chopped. Paddy husk was boiled in water for 15 to 20 minutes and the contents were filtered two days before to the production of the herbal kunapajala

4. One litre of each type of milk and butter milk was placed into the drum. After adding all the ingredients and stirring once with a wooden stick, water was poured until the lid's opening was reached. The lid was closed when everything was prepared.

5. Stir everything for ten minutes each morning and evening with a wooden stick.

6. When the fermentation process starts, we can observe the bubbles on top of the solution. When the bubbles stop forming after 20 to 25 days, the herbal kunapajala is prepared for field use.

5. Amudham karaisal

Plant growth is catalysed by Amudham solution. This solution immediately promotes leaf growth. It keeps insects away as well.

Preparation

Combining one litre of cattle urine, one kilogramme of manure, and 250 grammes of jaggery with ten litres of water, this can be made in a day.

Use: spray after adding one litre of this solution to ten litres (for a 10% solution).

6. Brahmastra

When applied at a rate of 6–8 litres per 200 litres of water per acre, Brahmastra efficiently eradicates fruit borer, pod borer, and sucking pests. Following preparation, it must be used within a month.

Preparation

1. Ten litres of Desi cow urine and a paste made from two kilogrammes of neem, castor, datura leaves, pongamia (karanj), and custard apple, among other ingredients.

2. After crushed paste is boiled and filtered, and fermented for 48 hours in shade.

7. Sonasthastra

Its helping to protect plants from fungi and pest.

Preparation

1. 200 grammes dry ginger, 5 litres desi cow's milk, and 200 litres water. Grind dry ginger till powdery.

2. Boil the mixture in 2 litres of water.

3. When only one litre remains, cool it down. In a pot, bring 5 litres of indigenous cow milk to a boil once and allow the milk to cool completely. Remove the milk cream and use it for domestic purposes.

4. Use a cloth to sieve the ginger water and hot milk mixture. Spray 200 litres of water over a one-acre crop. It is used to suppress fungal growth.

8. Saptdhanyankur

For plants, saptdhanyankur is a tonic. Utilising this during the fruiting (production) phase improves the quality of flowers, fruits, and vegetables.

Preparation

1. Black sesame seeds should be soaked in water in a basin. Give it a day to rest. The following stage is carried out after a day.

2. Fill a different bowl with water and soak the black gramme, green gramme, cow pea, moth bean, chick pea, and wheat seeds. Soak it for a full day. A day later, the following step is taken.

3. Remove the water from all seven varieties of seedlings the following day. Wrap the seeds in a cloth and place them in a shaded area. Separately, store the drained water. Until the seeds grow with a minimum of 1 centimetre of root, they are held in place.

4. Using a wooden mantle, smash the seeds once they have sprouted. Avoid using a mixer grinder.

5. Pour cow urine into a plastic container filled with water. Mix the seed after adding the water that was used to soak it. Mix the seed pulp thoroughly after adding it to the solution. To stir the solution, use a wooden stick. Put the gunny bag over the tank. You should leave the solution for two hours.

6. Filter the solution after two hours; it should be utilised during the following twenty-four hours.

NUCLEOPOLYHEDROSIS VIRUS (BMNPV) IN SILKWORM

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Abstract

Though the silkworm (*Bombyxmori*) form the foundation of the world's silk industry, sericulture is seriously threatened by their vulnerability to illnesses like Nuclear Polyhedrosis Virus (NPV). The highly infectious virus known as NPV, which is brought on by the *Bombyxmori* nucleopolyhedrovirus (*BmNPV*), disrupts the production of silk by causing significant larval death. In addition to providing useful prevention and control techniques, this article examines the signs, causes, and economic effects of NPV. Sericulturists can protect their livelihoods and the long-term viability of the silk business by comprehending and treating this disease.

Introduction

Sericulture, the practice of cultivating silkworms for silk production, supports millions of people worldwide. The silkworm, *Bombyx mori*, is central to this industry, but it faces constant threats from diseases like pebrine, muscardine, and grasserie. Among these, Nuclear Polyhedrosis Virus (NPV), caused by *Bombyxmori*nucleopolyhedrovirus (*BmNPV*), is the most destructive. NPV can devastate entire silkworm populations, causing 80–100% mortality in affected batches. In India, one of the world's largest silk producers, NPV outbreaks reduce production by 20–30%, leading to significant financial losses. Infected silkworms stop feeding, become sluggish, and die, leaving farmers without harvests. This not only disrupts silk production but also puts the livelihoods of small-scale farmers who rely on sericulture as their primary source of revenue at risk.

To combat NPV, farmers can adopt better rearing practices, maintain strict hygiene, and use disease-resistant silkworm breeds. These strategies can help reduce the virus's impact, offering hope for a more resilient and sustainable silk industry.

Nuclear Polyhedrosis Virus (NPV)

The **Grasserie** disease, caused by the *Bombyx mori* nucleopolyhedrosis virus (**BmNPV**), is one of the most **dominant and serious viral diseases** affecting silkworms, particularly in **tropical countries**, where it occurs **throughout the year**. BmNPV belongs to the family **Baculoviridae** and genus **Alphabaculovirus**. It is the **most harmful virus** in the sericulture industry, often leading to **severe economic losses**. In India, **over 50% of silk cocoon crop losses** are attributed to BmNPV infection.

The various names used in different countries are Grasserie (French), Milky disease, Jaundice (American), Giallume (Italy), Nobyo (Japan), Gelbsucht (Germany). In India, Halu-hula (Karnataka), Rasa (West Bengal), Pola purugu (Andhra Pradesh), Paalpoochi (Tamil Nadu), Aab-Baimair (Kashmir). The names often refer to the **yellowish color** of the diseased larvae or their **swollen, fatty appearance**. The disease was first reported by **Nysten**, and the causative agent, BmNPV, was earlier referred to as *Borriinabombycis*.

Occurrence

In India, BmNPV occurs year-round but shows seasonal variation. The highest prevalence is observed during summer (55.35%), followed by winter (41.66%) and the rainy season (32.97%). The *Bombyx mori* nucleopolyhedrovirus (BmNPV), a very destructive virus in the Baculoviridae family (subgroup A), results in significant financial losses in sericulture. The size of the viral particles is around 330 x 80 nm, whereas the rod-shaped, enclosed virions are approximately 50 x 250 nm. The virus has a circular, double-stranded genome that ranges in size from 80 to 200 kilobases (kb).

BmNPV replicates in the nucleus of host cells and infects adipose tissue, tracheal epithelial cells, cutaneous cells, blood cells, and infrequently, silk gland cells. A key feature of BmNPV is the formation of polyhedra, which are crystalline protein structures that protect the virus from environmental damage and range in size from 3 to 6 micrometres (µm). These polyhedra often shaped as octadecahedrons, hexahedrons, tetragons, or trigons, aid in the spread of the disease when silkworms eat contaminated mulberry leaves.

Causes of disease

- Presence of BmNPV polyhedra (occlusion bodies) in the environment. High viral load - A single infected larva produces billions of polyhedra.
- Polyhedra are highly stable and resistant to UV rays, heat, and chemicals, persisting for years.
- High temperature and humidity, especially during summer and rainy seasons
- Sudden fluctuations in temperature and humidity and poor ventilation in rearing rooms, creating damp conditions.
- Ineffective disinfection of rearing trays, equipment, and rooms.
- Feeding tender mulberry leaves during late larval stages.
- Overcrowding of larvae in rearing beds.
- Poor hygiene conditions like contaminated seat papers, rearing beds, and mulberry leaves and also stress conditions like starvation, excessive moisture, and inadequate larval spacing assist in causes of disease.

Symptoms

The **external symptoms of Bombyxmorinucleopolyhedrosis virus (BmNPV)** infection in silkworms, particularly in the **fourth and fifth instars larvae**, become visible about a **week after infection**.

Stage	Symptoms
Early Stage	- Slight sluggishness - Oily and shiny skin
Advanced Stage	- Swelling of inter-segmental regions - Lethargy and loss of appetite - Shiny and yellowish body - Hyperactivity - Crawling and hanging - Rupturing of skin - White ooze with polyhedra - Peripheral crawling - Loss of clasping power - Death - Rotting and secondary infections - Polyhedra in cell nuclei - Restlessness and fatigue

Site of infection

BmNPV primarily infects the **midgut epithelial cells** and then spreads to other tissues, including the **trachea, fat body, epidermis, hemocytes, and silk glands**.

Infection cycle of BmNPV

1. Ingestion of Contaminated Food: Silkworm feeds on mulberry leaves contaminated with polyhedra.
2. Dissolution of Polyhedra in Midgut: Polyhedra reach the digestive tract and dissolve in the alkaline digestive fluid, releasing virions.
3. Invasion of Midgut Epithelial Cells: Virions pass through the peritrophic membrane and invade columnar epithelial cells in the midgut, causing primary infection.
4. Virus Multiplication in Nucleus: Virions enter the nucleus of infected cells and begin replication.
5. Formation of Propolyhedra: Early-stage polyhedra, called propolyhedra (0.2–0.4 μm in diameter), form around a dense central mass.

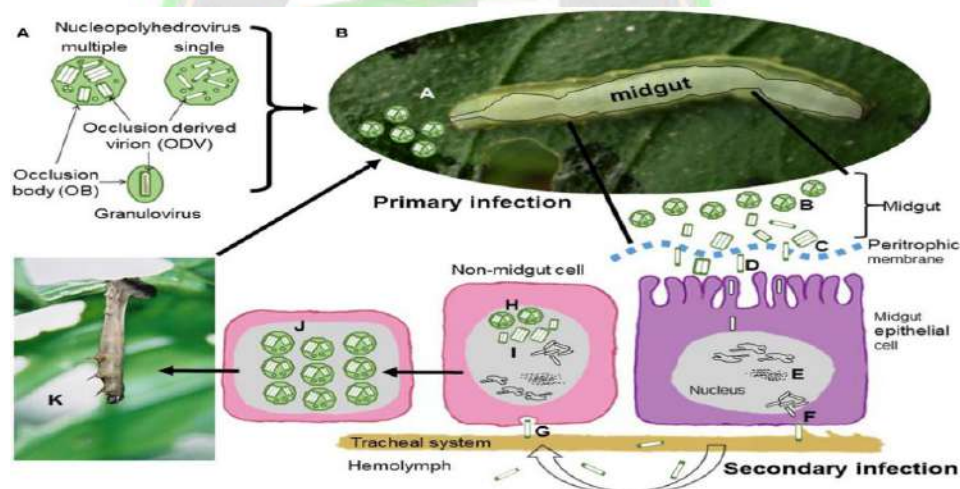


Figure 1: Schematic representation of baculovirus structure and infection cycle
(Williamset al., 2017)

6. Maturation of Polyhedra: Propolyhedra grow into mature polyhedra, filling the nucleus.
7. Cell Destruction and Release of Polyhedra: The nucleus is destroyed, and mature polyhedra are released into the hemolymph.
8. Spread of Infection: Polyhedra and virions spread through the hemolymph, infecting other tissues and cells. Infected larvae give the hemolymph its milky appearance.

9. Contamination of Environment: Infected larvae release polyhedra into the environment through body fluids or dead larvae, contaminating mulberry leaves, rearing trays, and seat papers.
10. Transmission to Healthy Larvae: Healthy larvae ingest contaminated food, continuing the infection cycle

Alternate host

Lepidopteron insects including *Philosamia*, *Samiaricini*, *Lymantria*, *Dendolimus*

Preventive Measures

Disease-Free Eggs: Use certified disease-free eggs; disinfect with 2% formalin.

Hygiene & Sanitation: Disinfect rearing facilities, equipment, and maintain personal hygiene. Properly dispose of infected waste.

Environmental Control: Maintain 24–28°C and 70–80% humidity; ensure proper ventilation and avoid sudden fluctuations.

Feeding Practices: Use fresh, clean mulberry leaves; avoid tender leaves in late instars; disinfect leaves with 0.1% bleach.

Larval Management: Avoid overcrowding, detect infections early, isolate infected batches, and ensure proper spacing.

Stress Reduction: Prevent starvation, minimize handling, and provide adequate care.

Resistant Strains: Use BmNPV-resistant silkworm varieties like **CSR2, CSR4, and double hybrids like SH6 × NB4D2**

Conclusion

The fight against NPV in silkworms is not just a battle for healthier larvae but a struggle to preserve an ancient industry that supports millions of livelihoods worldwide. By recognizing the early signs of NPV, implementing strict hygiene practices, and adopting resistant silkworm strains, sericulturists can significantly reduce the risk of outbreaks. While the threat of NPV remains, the combination of scientific knowledge and practical farming strategies offers a path forward. As we continue to innovate and adapt, the silk industry can overcome challenges like NPV, ensuring that the legacy of silk production endures for generations to come. The key lies in vigilance, education, and a commitment to sustainable practices, empowering farmers to protect their silkworms and secure the future of this timeless craft.

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SANGHUANGPORUS SANGHUANG – AN OVERVIEW

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Introduction

Sanghuang, a fungi was first recorded more than two thousand years ago in *Shen Nong Materia Medica*, the earliest monograph on traditional Chinese medicine. Since 1968, *Sanghuangporus spp.* is one of the most effective medicinal fungi for the treatment of cancer (Dong et al., 2009), when Japanese scholars first discovered the therapeutic effect of extracts of *Sanghuangporus spp.* This paper highlights the role of *Sanghuangporus sp.*

What is bracket mushroom?

Bracket fungi or shelf fungi, is the macrofungi under the phylum Basidiomycota. Bracket fungi are usually tough and sturdy. They produce shelf or bracket shaped fruiting bodies called conks. These lie in a close group of horizontal rows. Brackets can range from only a single row of a few caps, to dozens of rows of caps that can weigh several hundred pounds. They are mainly found on both living and dead trees and woody debris. Some form annual fruiting bodies while others are perennial and grow larger year after year.



Sanghuangporus spp

Sanghuangporus is one of the most important groups of medicinal wood inhabiting macrofungi, has been used in traditional Chinese medicine for the past two centuries. A total of 18 species have been described under the genus *Sanghuangporus*, 11 are distributed in China, specifically, *S. alpinus*, *S. baumii*, *S.*



lonicericola, *S. quercicola*, *S. sanghuang*, *S. subbaumii*, *S. toxicodendri*, *S. vaninii*, *S. vitexicola*, *S. weigela*, and *S. zonatus*. The powders or chips of basidiocarps are consumed as supplements in the diet.

- (A) *S. alpinus*
- (B) *S. lonicerinus*
- (C) *S. sanghuang*
- (D) *S. baumii*
- (E) *S. vaninii*
- (F) *S. lonicericola*



Host plant of *Sanghuangporus spp*

Primary Host plants:

Due to their unique growth mechanisms, stringent relationships with host plants, and specific locations of occurrence, wild *Sanghuangporus sp.* are relatively rare. For example, *S. sanghuang* grows only on *Morus*, primarily on *Morus alba* (white mulberry) and other species have not been successfully cultivated.

Secondary Host plants

Some of the secondary host tree species that also supporting their growth to some extent are

- *Syringa* (lilac),
- *Populus* (popular),
- *Alnus* (alder),
- *Juglans* (walnut),
- *Lonicera* (honeysuckle),
- *Quercus* (oak) and
- *Weigela*.

Extraction and purification

To extract bioactive components from *Sanghuangporus s.*, the fruiting bodies are typically dried, powdered, and then extracted using hot water or ethanol, depending on the target compounds, often with ultrasonic assistance.

Preparation:

- The process begins with harvesting the *Sanghuangporus* fruiting bodies.

- These are then dried and ground into a fine powder, which is necessary for efficient extraction.

Extraction Methods:

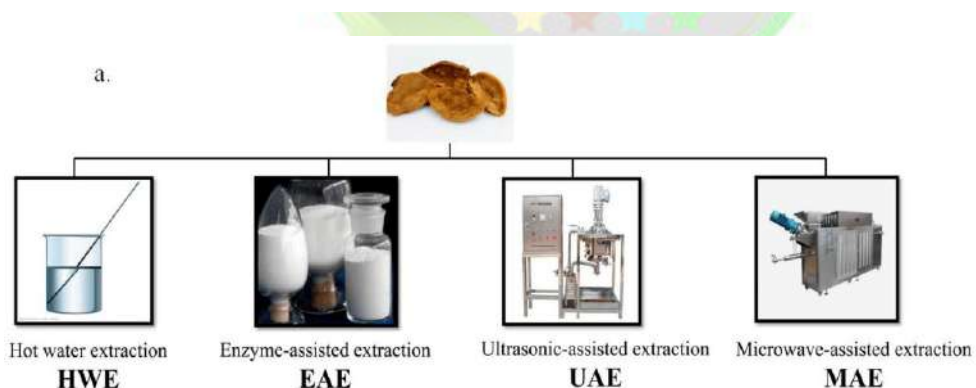
- **Hot Water Extraction:** This method is used to extract water soluble polysaccharides and other compounds.
- **Ethanol Extraction:** This method is used to extract ethanol soluble components
- **Ultrasonic Assistance:** Ultra sonication can enhance the extraction process by improving the penetration of the solvent into the fungal material and accelerating the extraction rate.

Alternative Methods:

- **Deep Eutectic Solvent (DES) Method:** This is a newer, environment friendly method that uses DES as a solvent, offering potential advantages over traditional organic solvents.

Mycelia Extraction:

- The mycelia (the vegetative part of the fungus) can also be extracted using similar methods as the fruiting bodies.
- Mycelia can be obtained through liquid fermentation.

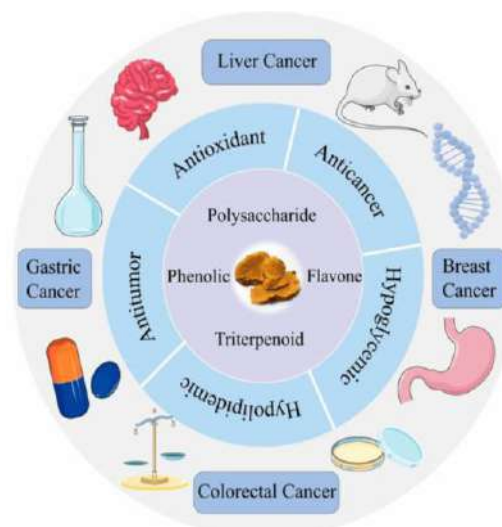


Purification:

The extracts can be further purified using traditional columns, synthetic polymers, or microporous resin.

Pharmaceutical uses of *Sanghuangporus sp.*

As a group of rare medicinal fungi, *Sanghuangporus sp.* was widely used for treating gynecological diseases, protecting liver and stomach, expelling toxins, and achieving other therapeutic purposes. *Sanghuang* has attracted extensive attention due to its potential utility in functional foods, biomedical products, and the drug industry. In recent years, multifarious bioactive compounds have been identified in *Sanghuang*, including polysaccharides,



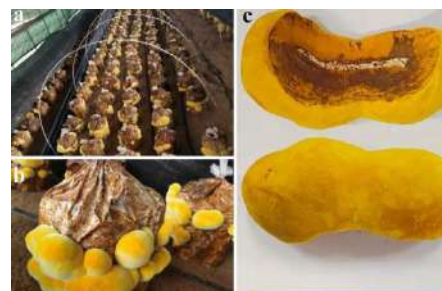
polyphenols, flavonoids, triterpenoids, and ascorbic acids. In addition to anti-tumor activity, numerous studies have confirmed the potent antioxidant, antimicrobial, anti-inflammatory, hepatoprotective, anti-diabetic and immunological properties of *Sanghuang*.

Role of *Sanghuangporus sp.* in prevention of COVID

Angiotensin II is the main effector molecule of the RAS (Renin Angiotensin System) in human. It causes increase in blood pressure, influences renal tubuli to retain sodium and water and stimulates aldosterone release from adrenal gland. Angiotensin converting enzyme 2 (ACE2) is the primary receptor of the COVID-19 virus, and its binding to the spike protein plays a critical role in viral entry into host cells and subsequent infection. Blocking this binding event reduces viral receptivity to the ACE2 receptor and represents a strategy to prevent infection with COVID-19. Upon infection with SARS-CoV-2, the expression of ACE2 decreases, which may subsequently lead to elevated angiotensin levels and worsen clinical outcome. *S. sanghuang* and its phenolic compounds (Hispidin, DBA, PAC, PAD, CA) can decrease the expression of ACE2 and have a latent capacity to prevent SARS-CoV-2 infection.

Commercial cultivation of *Sanghuangporus sp.*

Due to the above-mentioned health benefits, the demand for fruitbodies of *Sanghuangporus* in China increases year by year. Of the 14 species of *Sanghuangporus* fungi exist throughout the world, only *S. vaninii* and *S. baumii* can be artificially



cultivated on a large scale and also far more popular with customers in China. *Sanghuangporus sanghuang* has been cultivated in the laboratory.

Conclusion

Sanghuangporus, a wild traditional medicinal mushroom has various beneficial components in it. Only a few countries such as China and Japan are aware of its medicinal importance. Due to its wild nature, its value remains hidden and lacks importance in many countries.

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SYNTHETIC BIOLOGY FOR ENVIRONMENTAL CONSERVATION: ENGINEERING NATURE TO HEAL THE PLANET

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Abstract

Synthetic biology is transforming environmental conservation by enabling the creation of engineered organisms and pathways that address pollution, climate change, and biodiversity loss. Through advanced genetic design, scientists can develop microbes to efficiently degrade persistent pollutants such as plastics and hydrocarbons, and engineer algae to capture atmospheric carbon dioxide at high rates. These innovations support faster ecosystem restoration and sustainable production of bio-based materials and fuels. While synthetic biology offers significant promise for large-scale environmental solutions, its deployment requires careful management of ecological risks and ethical considerations. As the field evolves, synthetic biology is poised to become a key component of future strategies for global environmental sustainability.

Keywords: Synthetic biology, environmental conservation, bioremediation, engineered microbes,

Introduction

Synthetic biology is an emerging scientific field that blends principles from biology, engineering, computer science, and chemistry to design and build new biological systems or redesign existing ones for useful purposes. Unlike traditional genetic engineering, which typically modifies one or a few genes, synthetic biology enables scientists to construct entire genetic circuits or metabolic pathways from scratch. This approach allows for unprecedented

control over the functions and behaviours of living organisms. Environmental conservation faces growing challenges due to rapid industrialization, urbanization, climate change, and the accumulation of pollutants in ecosystems.

Traditional methods of conservation and remediation, while valuable, often struggle to keep pace with the scale and complexity of these problems. Synthetic biology offers a new toolkit for addressing these environmental issues by enabling the creation of organisms specifically tailored to perform tasks such as breaking down pollutants, capturing atmospheric carbon, restoring degraded habitats, or even monitoring environmental health in real time. By leveraging the power of synthetic biology, researchers can develop highly efficient, targeted, and scalable solutions that complement or surpass natural processes. This not only holds promise for cleaning up contaminated environments but also for supporting sustainable agriculture, preserving biodiversity, and mitigating the effects of climate change. As a result, synthetic biology is rapidly gaining recognition as a transformative approach in the quest for a more sustainable and resilient planet.

Synthetic Biology and Ecosystem Sustainability

Synthetic biology provides new strategies to enhance ecosystem sustainability by targeting the root causes of environmental degradation. Engineered microorganisms and plants can be deployed to restore habitats, improve soil fertility, and promote plant growth. For example, synthetic biology enables the development of biocatalysts for water treatment and the construction of metabolic pathways that support the breakdown of pollutants and the cycling of nutrients. These advances contribute to the resilience of ecosystems and support the restoration of degraded environments (San Román *et al*; 2025). In agriculture, synthetic biology can reduce environmental impacts by engineering crops that require fewer chemical inputs, such as pesticides and fertilizers. Genetically modified organisms can also be tailored to withstand environmental stresses, supporting food security while conserving biodiversity. However, these interventions must be carefully managed to avoid unintended ecological consequences and ensure that engineered organisms do not disrupt native species or ecosystem functions (IUCN, 2024).

Bioremediation and Pollution Management

A major application of synthetic biology is bioremediation, where engineered organisms are used to degrade or detoxify pollutants. Synthetic biology enhances this process by enabling

precise genetic modifications that allow microbes or plants to sense and respond to specific contaminants, including persistent chemicals like plastics, hydrocarbons, and heavy metals. Engineered biosensors can detect pollutants and trigger the activation of metabolic pathways for their breakdown, making remediation more efficient and targeted (Lea-Smith *et al*;2025). Furthermore, synthetic biology facilitates the production of biodegradable plastics and the conversion of waste into valuable products such as biofuels. These strategies not only mitigate pollution but also support circular economy principles and sustainable resource management. The integration of synthetic biology with digital technologies, such as automated bioreactors and cloud-based data analysis, further enhances the scalability and effectiveness of these environmental interventions.

Biodiversity Conservation and Restoration

Synthetic biology holds significant potential for biodiversity conservation and restoration. It can be used to protect endangered species by enhancing their resistance to diseases or environmental stressors. Gene editing technologies, such as CRISPR, can help control invasive species or disease vectors, reducing threats to native biodiversity without harming non-target species. Additionally, synthetic biology may offer ways to restore genetic diversity in threatened populations or even revive extinct species through de-extinction efforts. While these prospects are promising, they also raise complex ethical and ecological questions regarding the release of engineered organisms into natural habitats. Ongoing research and policy development are focused on balancing potential benefits with risks to ecosystem integrity (Lean, C. H. 2024).

Environmental Monitoring and Biosensing

Effective conservation requires robust monitoring systems to detect and respond to ecological changes. Synthetic biology has enabled the development of biosensors—engineered organisms or cell-free systems that can detect pollutants, heavy metals, or other environmental markers with high precision. These biosensors can be integrated with Internet of Things (IoT) devices and artificial intelligence to provide real-time, remote monitoring of environmental conditions. For example, biosensors can trigger engineered microbes to activate pollutant-degrading pathways in response to detected contaminants, enabling adaptive and targeted bioremediation. The integration of synthetic biology with digital and geospatial technologies further enhances the scalability and effectiveness of environmental interventions, supporting

continuous monitoring and rapid response in complex ecosystems. Table 2 explains the difference between natural bioremediation and synthetic bioremediation.

Table 1: Comparison of Natural vs. Synthetic Biology - Based Bioremediation Methods

Feature	Natural Bioremediation	Synthetic Biology-Based Bioremediation
Degradation Efficiency	Moderate; often limited by native metabolic pathways and environmental conditions. Typical removal rates for hydrocarbons range from 40–70% over several months.	High; engineered microbes or enzymes specifically target and break down recalcitrant pollutants, often achieving > 90% removal in shorter periods
Cost	Generally low; uses indigenous microbes and minimal inputs, but may require longer treatment times and larger land areas.	Moderate to high; initial development and deployment costs for engineered organisms or enzymes, but potentially lower operational costs due to faster and more complete remediation.
Time Required	Slow; can take several months to years depending on contaminant and site conditions.	Fast; synthetic biology methods can reduce remediation time to weeks or a few months.
Specificity	Low to moderate; relies on naturally occurring metabolic diversity, which may not be optimal for all pollutants.	High; engineered pathways and organisms can be tailored for specific contaminants, including those resistant to natural degradation.
Environmental Impact	Minimal; uses native organisms, but may be less effective for persistent pollutants.	Variable; potential for unintended ecological effects, but can be designed for minimal off-target impact.

Challenges, Risks and Future Directions

Despite its transformative potential, synthetic biology for environmental conservation faces several challenges. These include ethical concerns about releasing engineered organisms into the wild, potential unintended ecological effects, and the need for robust regulatory frameworks to ensure biosafety. Policy development must keep pace with technological advances, and interdisciplinary collaboration is essential to guide the responsible use of synthetic biology. Future research should focus on improving the predictability and controllability of engineered organisms, developing standardized risk assessment protocols, and engaging with local communities to ensure that synthetic biology solutions align with societal values and conservation priorities. As the field advances, it will be crucial to balance innovation with precaution to maximize benefits while minimizing risks to ecosystems and biodiversity.

Conclusion

Synthetic biology represents a paradigm shift in environmental conservation, offering innovative tools for ecosystem restoration, pollution management, biodiversity protection, and environmental monitoring. By harnessing the power of engineered biology, humanity can address some of the most pressing environmental challenges of our time. However, realizing the full potential of synthetic biology will require careful consideration of ethical, ecological, and societal factors, as well as sustained investment in research, regulation, and public engagement.

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TRANSGENE-FREE GENOME EDITING: THE NEXT BIG STEP IN CROP IMPROVEMENT

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Introduction

The surging global population has intensified concerns over food security, placing unprecedented pressure on agricultural production systems worldwide. Climate change, shifting environmental conditions, and soil degradation pose significant threats to crop productivity, disrupting traditional agricultural practices and challenging global food systems (Ntui et al., 2020). Additionally, the prevalence of monoculture cropping patterns has eroded genetic diversity in plants, while the reliance on a limited number of staple crops for large-scale production has weakened their resilience to environmental stresses. This diminished vigor leaves crops increasingly vulnerable to both biotic and abiotic stresses, heightening the risk of significant agricultural losses.

Traditional crop improvement methods, such as conventional breeding and molecular approaches, face limitations in addressing these complex and immediate challenges. These methods are time-consuming, labor-intensive, and restricted to traits within sexually compatible species. Furthermore, they risk the unintentional transfer of undesirable traits. While marker-assisted selection has improved the efficiency of trait identification, it remains dependent on the existing genetic variation within a crop's gene pool, further constraining its effectiveness in overcoming current agricultural challenges (Yıldırım et al., 2023).

To address this genome editing has emerged as a transformative tool for genetic modification in plants, offering diverse opportunities for crop improvement. Among the site-directed nuclease (SDN)-based genome-editing techniques—such as meganucleases, zinc-finger

nucleases (ZFN), transcription activator-like effector nucleases (TALEN), and clustered regularly interspaced short palindromic repeats (CRISPR)/CRISPR-associated (Cas) systems (Kamburova et al., 2017)—CRISPR-Cas9 has garnered widespread attention due to its simplicity, efficiency, and versatility. However, the integration of foreign DNA (transgenes) into plant genomes during the editing process poses challenges for legislative and regulatory approval of edited crops and raises public concerns about biosafety and environmental impacts (Feng et al., 2013).

Traditionally, obtaining transgene-free plants required the segregation of integrated DNA through selfing or crossing with wild-type plants—a process that is labor-intensive, time-consuming, and not feasible for all crops. To overcome these limitations, transgene-free genome editing methods have been developed, enabling precise genetic modifications without leaving behind foreign DNA (Bhattacharjee et al., 2023). These advancements not only address regulatory and public concerns but also broaden the scope of genome editing applications in diverse plant species. This review highlights the principles, methodologies, applications, and future prospects of transgene-free genome editing, with a particular focus on its potential in banana improvement.

Transgene-Free Genome Editing: Concept and Significance

Transgene-free genome editing leverages temporary delivery systems for CRISPR-Cas9 components, ensuring that plants remain free of foreign DNA post-editing. This innovative approach streamlines the regulatory approval process and enhances public acceptance by producing plants indistinguishable from those developed through traditional breeding techniques (Bhattacharjee et al., 2023). The absence of foreign DNA in the final product increases the potential for widespread adoption and utility. This method is particularly significant in the context of genetically modified organisms (GMOs), which are subject to stringent regulations in many countries. These regulations often result in lengthy approval timelines, delaying the commercialization of improved crop varieties. Transgene-free editing offers a solution by circumventing these regulatory complexities, thus expediting the development and deployment of enhanced agricultural crops (Townson, 2017). Furthermore, it directly addresses consumer concerns about GMO safety and environmental impacts, making it a more publicly acceptable technology that supports sustainable agricultural practices.

Tools for Transgene-free Genome editing

Several strategies have been developed to achieve transgene-free genome editing in plants, offering transient delivery of editing tools (CRISPR-Cas) via non-integrating methods (Virus like particles, electroporation) and template-free systems (Prime and Base editing). These approaches ensure genome modifications without residual foreign DNA. One of the most widely used methods is the delivery of CRISPR-Cas9 ribonucleoproteins (RNPs). In this approach, pre-assembled complexes of Cas9 protein and guide RNA (gRNA) are introduced into plant cells. These RNPs introduce the desired edits and are subsequently degraded, leaving no trace of foreign DNA (Zhang *et al.*, 2016). This method is highly precise and reduces the risk of off-target effects, making it a preferred choice for regulatory compliance and agricultural applications (Woo *et al.*, 2015).

Another effective approach involves transient expression systems, such as *Agrobacterium*-mediated delivery or virus-based systems. In these systems, CRISPR components are expressed temporarily and then degraded, allowing for efficient editing without the permanent integration of foreign DNA. This is particularly advantageous for rapid trait improvement and meeting regulatory requirements (Li *et al.*, 2018). Additionally, particle bombardment and protoplast transformation are employed to deliver CRISPR components without permanent integration. Particle bombardment involves shooting gold or tungsten particles coated with CRISPR components into plant cells, while protoplast transformation involves treating plant cells without cell walls with CRISPR components (Svitashevet *et al.*, 2016).

Base editing is another technique that enables the conversion of one DNA base pair into another without inducing double-strand breaks useful for creating single-nucleotide polymorphisms (SNPs) associated with desirable traits, offering a high level of precision in genome modification (Gaudelli *et al.*, 2017). This approach uses engineered Cas9 variants fused with deaminase enzymes to achieve targeted base changes, such as C-to-T or A-to-G conversions.

Promoter editing is another innovative strategy that involves modifying regulatory regions of genes to fine-tune gene expression without altering the coding sequence. This approach is particularly useful for optimizing traits such as stress tolerance, yield, and nutrient use efficiency. By targeting specific promoter elements, researchers can create allelic variations

that modulate gene expression levels, enabling precise control over plant phenotypes (Rodríguez-Leal *et al.*, 2017).

Furthermore, fluorescence-based technologies enable real-time monitoring of editing events, allowing researchers to track the success of genome modifications and optimize editing protocols (Chen *et al.*, 2016). The TKC (Targeted Knock-in and Knock-out) and CASE (CRISPR-Assisted Synthetic Evolution) toolkits are advanced platforms for genome editing. TKC facilitates precise gene knock-ins and knock-outs, while CASE enables large-scale genomic rearrangements and synthetic evolution. These toolkits leverage CRISPR-Cas9 to introduce targeted mutations, insertions, or deletions, providing a powerful means to study gene function and engineer desirable traits (Lu *et al.*, 2017).

Together, these transgene-free genome-editing tools have been successfully employed across various crops to introduce precise genetic modifications. Among these, the use of CRISPR-Cas9 RNPs and innovative approaches like transgene-free editing by grafting stand out for their impact. These advancements not only improve the efficiency and precision of genome editing but also address critical regulatory challenges, paving the way for the development of resilient crops with enhanced traits.

CRISPR-Cas9 Ribonucleoproteins (RNPs)

Delivering programmable nucleases like Cas9 into plant cells has traditionally relied on non-integrating plasmids, a widely used method that comes with significant limitations. Endogenous nucleases in plant cells often degrade transfected plasmids, leading to the insertion of small DNA fragments into both on-target and off-target sites. These unintended integrations raise regulatory concerns, particularly for agricultural crops that require stringent approval processes (Andersson *et al.*, 2018).

An emerging alternative involves the use of preassembled Cas9 protein–gRNA ribonucleoproteins (RNPs), which offer distinct advantages over plasmid-based methods. RNPs mitigate the risk of recombinant DNA integration into the host genome by employing a transient, protein-and-RNA-only system. RNA-guided endonucleases (RGEN)-RNPs cleave target sites immediately upon transfection and are subsequently degraded by endogenous proteases. This rapid degradation minimizes mosaicism and reduces off-target effects in regenerated plants (Liang *et al.*, 2017). Additionally, this approach circumvents the need for codon optimization or promoter selection, making it adaptable to a wide range of crop species.

The formation of RNPs involves mixing purified Cas9 protein with an excess of guide RNAs (gRNAs) targeting specific genes *in vitro*. These preassembled RGEN-RNPs are then introduced into protoplasts—plant cells with their cell walls removed—using polyethylene glycol (PEG)-mediated transfection. This method ensures efficient delivery of the RNPs into the target cells. Mutation rates can be assessed using the T7 endonuclease I (T7E1) assay and targeted deep sequencing (Kim et al., 2017). Mutations are typically detected within 24 hours of transfection, demonstrating the rapid action of RNPs, often before the first cell division cycle is completed.

This technique has demonstrated high germline transmission rates and low frequencies of off-target mutations, making it a promising tool for DNA-free agricultural crop improvement (Malnoy et al., 2016). By eliminating the use of plasmid DNA, the RNP-based approach reduces the risk of unintended genomic integrations, ensuring greater precision in genome editing. It has been successfully applied to a variety of crops, including wheat, rice, and tomatoes, to enhance traits such as disease resistance, drought tolerance, and nutritional quality (Lowder et al., 2015; Ma et al., 2015; Wolter et al., 2018). This DNA-free approach is poised to revolutionize crop genome editing, providing a precise, efficient, and regulatory-friendly alternative for improving agricultural productivity and sustainability.

Transgene-Free Genome Editing by Grafting

A groundbreaking approach to achieving transgene-free genome editing involves the grafting of wild-type shoots onto transgenic donor rootstocks. This method capitalizes on the natural ability of plants to exchange genetic material across graft junctions, enabling the transfer of edited genomes from transgenic rootstocks to non-transgenic shoots. This innovative technique was recently demonstrated in *Arabidopsis thaliana* and *Brassica rapa*, showcasing the potential of graft-mediated genome editing (Yang et al., 2023).

The mechanism underlying this approach involves the use of mobile CRISPR RNAs. These RNAs, including Cas9 mRNA and guide RNA (gRNA), are engineered with tRNA-like sequences (TLS) to facilitate their long-distance transport from the rootstock to the scion (Huang, 2023). In this system, the rootstock is a transgenic plant that expresses TLS-fused CRISPR components, while the scion—a non-transgenic shoot—is grafted onto the rootstock.

During the editing process, mobile RNAs migrate into the reproductive tissues of the scion, leading to heritable genome edits in the resulting seeds without incorporating foreign

DNA. This process occurs in two main steps. First, the transgenic rootstock is developed by introducing CRISPR-Cas9 components into its genome. These components are programmed to target specific genes for editing. Once the edits in the rootstock are established, wild-type shoots are grafted onto the transgenic rootstock. Over time, the edited genomes from the rootstock traverse the graft junction into the scion, culminating in heritable edits within the shoot tissue (Yang et al., 2023).

A key advantage of this method is that it produces edited plants without introducing transgenes into the shoot tissue. Since the CRISPR components remain localized in the rootstock, the scion remains transgene-free, rendering the final product more acceptable to regulators and consumers. Furthermore, this method is particularly advantageous for editing genes that are challenging to target using **conventional** approaches, such as those involved in root development or nutrient uptake (Gu et al., 2021). This technique holds significant promise for species that are recalcitrant to traditional transformation methods. By enabling the production of transgene-free edited plants, grafting offers a versatile and regulatory-friendly alternative for advancing crop improvement.

Application of Transgene-Free Genome Editing

Transgene-free genome editing has emerged as a transformative tool for improving various traits in crops, including disease resistance, abiotic stress tolerance, nutritional enhancement, and yield optimization. By avoiding the introduction of foreign DNA, this approach ensures the development of crops that align with regulatory and consumer preferences, while addressing critical challenges in agriculture.

One notable application involves the use of CRISPR-Cas9 ribonucleoproteins (RNPs) to develop wheat varieties resistant to powdery mildew, a pervasive fungal disease that significantly hampers wheat production worldwide (Zhang et al., 2016). Similarly, transgene-free genome editing has been employed to improve drought tolerance in rice, a vital trait for maintaining food security in regions experiencing the adverse effects of climate change (Shan et al., 2015).

Beyond stress tolerance, this technology has shown remarkable potential in enhancing the nutritional quality of crops. For example, maize has been edited to increase its nutritional content, providing a means to combat malnutrition (Svitashev et al., 2016). In another instance, potatoes were edited to reduce acrylamide levels, a potentially harmful compound that forms

during frying, thereby improving their safety and quality (Clasen et al., 2016). These advancements underscore the versatility and efficacy of transgene-free genome editing in addressing pressing agricultural issues, such as food security, climate resilience, and public health. A summary of key findings demonstrating the applications of this technology is provided in **Table 1**.

Table 1: Transgene-Free Genome Editing in Plants

Species	Gene Targeted	Method of Transfection	Responses/Findings	Reference
Wheat	MLO	CRISPR-Cas9 RNP	Resistance to powdery mildew	Zhang <i>et al.</i> , 2016
Tomato	RIN	CRISPR-Cas9 RNP	Extended shelf life and delayed fruit ripening	Li <i>et al.</i> , 2018
Rice	OsPDS	Transient expression	Improved drought tolerance	Shan <i>et al.</i> , 2015
Maize	ZmIPK1	Particle bombardment	Increased phosphate content and improved nutritional value	Svitashevet <i>al.</i> , 2016
Soybean	GmFT2a	CRISPR-Cas9 RNP	Early flowering and improved adaptation to shorter growing seasons	Li <i>et al.</i> , 2015
Barley	HvPM19	CRISPR-Cas9 RNP	Improved malting quality and drought tolerance	Lawrenson <i>et al.</i> , 2015
Citrus	CsLOB1	CRISPR-Cas9 RNP	Resistance to citrus canker disease	Jia <i>et al.</i> , 2017
Grapevine	MLO-7	CRISPR-Cas9 RNP	Increase resistance to powdery mindew	Malonyet <i>al.</i> , 2016
Apple	DIPM-1,	CRISPR-Cas9	Resistance to fire	Malonyet <i>al.</i> , 2016

	DIPM2, and DIPM-4	RNPs	blight	
Canola	FAD2	CRISPR-Cas9 RNPs	Improved oil quality with higher oleic acid content	Okuzakiet <i>al.</i> , 2018
Lettuce	LsNCED4	CRISPR-Cas9 RNPs	Improved shelf life and reduced post- harvest losses	Woo <i>et al.</i> , 2015
Cotton	GhCLA1	CRISPR-Cas9 RNPs	Improved fiber quality and yield	Wang <i>et al.</i> , 2018
Potato	StPPO2	CRISPR-Cas9 RNPs	Reduced Polyphenol Oxidases (PPOs)	González <i>et al.</i> , 2020
Rapeseed	SGT	CRISPR-Cas9 RNPs	Reduced sinapine level	Moss <i>et al.</i> , 2025
Sugarcane	ScALS	CRISPR-Cas9 RNPs	Herbicide resistance and improved crop management	Kannan <i>et al.</i> , 2018

Transgene-Free Genome Editing in Bananas

Bananas, a vital staple crop for millions globally, face critical challenges such as susceptibility to diseases like Fusarium wilt and limited genetic diversity. Transgene-free genome editing provides a promising approach to address these issues by improving banana traits without introducing foreign DNA, making the process more acceptable to regulators and consumers. One notable application of this technology is the use of CRISPR-Cas9 ribonucleoproteins (RNPs) to target genes associated with disease susceptibility in bananas. This approach has led to the development of edited plants with enhanced resistance to pathogens. Such advancements are particularly significant for Cavendish bananas, which dominate global production but are highly vulnerable to Fusarium wilt. Strengthening disease resistance in this variety can mitigate substantial losses in banana cultivation and ensure consistent supply. Beyond disease resistance, transgene-free genome editing has been employed to improve fruit quality and shelf life. These enhancements address key consumer demands and reduce post-harvest losses, further contributing to sustainability in banana production (Tripathi et al., 2024).

Given the banana's critical role as a primary food source in many regions, the application of transgene-free genome editing holds immense potential to bolster global food security. By enabling precise and efficient modifications, this approach offers a sustainable pathway to address the pressing challenges facing banana production while maintaining the genetic integrity of this essential crop.

Challenges and Future Directions

Transgene-free genome editing has revolutionized crop improvement, yet it faces several challenges that must be addressed to fully realize its potential. One significant hurdle is the efficient delivery of CRISPR components to a wide range of plant species and tissues. Many crops remain recalcitrant to regeneration from edited cells or protoplasts, limiting the ability to obtain whole plants from edited tissues. This is particularly problematic for species with complex or poorly characterized genomes.

Multiplex editing, which involves the simultaneous modification of multiple genes, poses additional complexities in transgene-free systems. The lack of stable, integrated editing machinery necessitates the precise and efficient assembly and delivery of all required components in a single transient application (Zhang et al., 2016; Chen et al., 2018; He et al., 2018). Despite these challenges, ongoing research is making strides toward addressing these limitations. Efforts are focused on developing advanced delivery methods, such as nanoparticle-based systems and electroporation techniques, to expand the range of editable crops. New CRISPR variants with enhanced specificity and efficiency are also being designed to improve editing outcomes while minimizing off-target effects.

Another critical challenge is the public perception of genome-edited crops. While transgene-free editing addresses many concerns associated with genetically modified organisms (GMOs), there remains a need for transparent communication and education about its benefits, safety, and potential impact on agriculture and food systems. Regulatory frameworks also require updates to differentiate transgene-free genome editing from traditional GMO technologies, ensuring fair and science-based evaluation. By overcoming these challenges, transgene-free genome editing stands poised to revolutionize agriculture. It offers a sustainable, precise, and consumer-friendly approach to improving crop traits, enhancing global food security, and addressing pressing issues such as climate resilience, disease resistance, and nutritional

deficiencies. Continued advancements in this field will pave the way for transformative innovations in agricultural biotechnology.

Conclusion

Transgene-free genome editing marks a groundbreaking advancement in plant biotechnology, providing a precise, efficient, and socially acceptable approach to crop improvement. By eliminating the integration of foreign DNA, this technology addresses regulatory and consumer concerns while offering immense potential for developing high-yielding, climate-resilient, and nutritionally enhanced crops. As global population growth accelerates and environmental challenges such as climate change and resource scarcity intensify, the need for innovative agricultural solutions has never been more critical. Transgene-free genome editing stands at the forefront of **this transformation**, offering tools to overcome these challenges sustainably. From enhancing disease resistance to improving stress tolerance and nutritional quality, this technology promises to reshape the agricultural landscape. With continued research, refinement, and public engagement, transgene-free genome editing is set to play a pivotal role in the future of sustainable agriculture, ensuring food security and environmental resilience for generations to come.

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NATURE'S FLAVORFUL POWERHOUSE FROM FARM TO TABLE - ONION FARMING AND HEALTH

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Introduction

Onions are the most commonly grown vegetables of the *Allium* family. They are known as Vaengayam (Tamil), Savala (Malayalam), Erulli (Kannada), Nirulli (Telugu), Pyaz (Hindi), and Piyaz (Bengali). Other similar vegetables are garlic, leek, and shallot. The onion plant has blue-green leaves, and the bulb at the bottom swells after a certain period. Onions are grown and consumed all over the world. They are usually served boiled. They can also be eaten raw and are used in pickles, sambars, and chutneys. Onions have a strong flavor and a sharp, pungent taste. It can be cultivated in different climates (temperate, tropical, and subtropical). Onions are delicious vegetables known for more than their texture and flavor. It is known for its strong, sharp, pungent taste. Onions are full of vitamins B6 and C, iron, and potassium. They contain allium and allyl disulfide. These compounds can reduce the risk of cancer, maintain healthy blood sugar, calm inflammation, and treat infections.

The ancient origin of the onion goes back to the western and eastern parts of Asia. There are many types of onions in the world, which means they were probably cultivated all over the world at the same time. According to information, onions were used in China as early as 5000 BC. Mainly due to the durability of onions in transportation and storage. The ancient Egyptians respected this vegetable, considering its spherical shape and concentric rings as a symbol of eternal life. Onions were also used in ancient Egyptian burials. The medical records of the Charaka Samhita (up to the 6th century BC) mention onion as a medicinal plant. Even a Greek physician from the 1st century AD (Pedanious Dioscorides), the father of pharmacognosy

documented the medicinal use of vegetables. It was the first European settler who brought onions to North America.

Different types of onions?

Onions are so widely used that almost everywhere in the world, onions are added to all culinary dishes. There are several types of onions:

Yellow onions - They have ivory white flesh surrounded by thick brown skin. They have a strong and sulfurous smell.

Sweet onions - These have a lighter, less opaque skin that surrounds the larger, slightly fattier body of the vegetable.

White onions - They have a papery white skin and are milder and sweeter than their yellow counterparts.

Red onions - These are mild and sweet enough to eat raw. The skin and flesh are deep magenta.

Shallots - These are smaller and have brown skin and purple flesh.

Green onions - These are immature bulbs that have not yet formed into bulbs.

Leek - It is shaped like an overgrown onion (a long-necked onion with a small bulb) and is often used in sauces and soups.

Small onion (*Allium cepa* var. *aggregatum*)

The scientific name of the small onion is (*Allium cepa* var. *aggregatum*) and belongs to the Alliaceae family. Shallots/small red onions/scallions have a special shape that makes them different from other members of the onion family. Shallots are prepared in thin layers. This allows them to mix well with sauces and dips that taste somewhere between garlic and onion. Shallots have a delicate and sweet taste with a touch of sharpness. Small red onions are rich in vitamins and minerals. 100 grams of shallots have 72 calories, 16.8 g of carbohydrates, 7.9 g of sugar and 2.5 g of protein.

Soil and season

Grows well in red loam to black soil with good drainage. It works well in a soil pH range of 6-7 without extremes of heat and cold. Onions are usually sown in April-May and October-November. It needs sufficient soil moisture during the growing season, but heavy rains occur during the germination and formation of bulbs, which affects the growth of crops.

Preparation for nursery

This is the most common method of irrigated crops because it gives high yields and large bulbs.

In the plains, seeds for the rabi harvest are sown in October-November. In the mountains, seeds are sown from March to June. The seeds are first sown in a well-prepared bed with a width of 90-120 cm, a height of 7.5-10.0 cm, and a length as per the requirement. The ratio of plant area to main field is approximately 1:20. The seed rate varies from 8-10 kg/ha. Seedlings of 15 cm height and 0.8 cm neck diameter are ideal for planting and this can be achieved in 8 weeks. However, it varies from 6 to 10 weeks, depending on soil, climate, and rainfall. It is customary to cover the seedlings during planting when they have emerged.

Field preparation and planting

Plow the soil finely and form ridges and furrows every 45 cm. Sow the bulbs on both sides of the ridge at a distance of 10 cm from each other. Water when seedlings are planted, and on the third day, and after every 30 cm, every week, or 120 cm, raised beds are formed and side beds are placed in the center of each box. Seedlings are planted in rows with a distance of 20 cm and 12 cm between plants. Six rows are planted in each bed, so 55,560 plants can be grown on one hectare. Watering is done after planting or planting bulbs. Complete irrigation is necessary to maintain consistent moisture. Stop watering 10 days before harvest.



Manure and fertilizers

Farm yard manure 25 t/ha should be applied one month before transplanting, Azospirillum 2 kg and Phosphobacteria 2 kg/ha and fertilizers of N 30 kg, P 60 kg, and K 30 kg/ha can be applied as basal and on the 30th day of sowing 30 kg N/ha can be given. For fertigation, 75% of the recommended total dose of superphosphate ie, 285 kg/ha as the main dose. Azospirillum and Phosphobacteria, each @ 2 kg/ha with FYM 50 kg and Neem cake @ 100 kg, are applied before the last ploughing.

Recommended water-soluble fertilizers for small onions

Water-soluble fertilizers are excellent for small onion cultivation as they provide quick nutrient absorption and boost plant growth efficiently.

- 19-19-19 (Balanced formula for early growth)
- 12-61-00 (High phosphorus for root development)
- 13-40-13 (For bulb initiation and strengthening)
- 00-52-34 (High potassium for bulb firmness and disease resistance)
- Calcium Nitrate (CaNO_3) – Improves bulb quality and prevents disorders.
- Magnesium Sulphate (MgSO_4) – Enhances photosynthesis and chlorophyll production.
- Boron (Boric Acid) – Essential for bulb formation and structure.
- Zinc Sulphate – Supports enzyme activities and plant metabolism.

Foliar spray

- DAP (Di-Ammonium Phosphate) solution – Promotes early root growth.
- Potassium Nitrate (KNO_3) – Strengthens bulb size and storage quality.

Apply fertilizers using drip irrigation or foliar spray for optimal absorption. Use low concentrations (0.5–1% solutions) to avoid leaf burn. Ensure consistent moisture for improved nutrient uptake. Apply micronutrients at critical growth stages, such as bulb formation and maturation.

Integrated pest and disease control

- Cultivation of two rows as barrier plants at the border of the field.
- Selection of healthy onion seed bulbs.
- Soil application of *Pseudomonas fluorescens* (1.25 kg/ha) + *Trichoderma viride* (1.25 kg/ha) + AM Fungi (VAM) (12.5 kg/ha) + Azophos (4kg/ha) + Neem cake 250 kg/ha.
- Installation of yellow sticky traps 12 nos./ha for thrips and leaf miners.
- Installation of pheromone traps 12 nos/ha for cutworm
- *Pseudomonas fluorescens* (5 g/l) + *Beauveria bassiana* (10 g/l) spray on 30 DAP and Azadirachtin 1% (2 ml/l) spray on 40 DAP.
- In case of leaf spot, spray Mancozeb 2 g/l or copper oxychloride 2.5 g/l and add Teepol 0.5 ml/l to the spray liquid.
- Application of Profenofos (2 ml/l) or Dimethoate (2 ml/l), or Triazofos (2 ml/l) as needed to control thrips/leaf breakers/cutworms.

- Tebuconazole (1.5 ml/l or mancozeb (2 g/l)/zineb (2 g/l) is required to manage purple blotch disease.



Harvest

The duration of the crop is 70 to 90 days. The yield of onion ranges from 12-16 t/ha which depend on the duration and variety of crop. Harvesting is done by pulling out plants when tops are drooping but still green. During the hot days when soil is hard, bulbs are pulled out with a hand-hoe. Clean and dry the bulbs for 4 days in shade soon after harvest.

Health benefits of onions

- Loaded with nutrients.
- Beneficial for heart health.
- Contains antioxidants and anti-cancer compounds.
- Helps control blood sugar.
- Increase bone density
- They have antibacterial properties
- Promote digestive health.

ROLE OF ARABLE AND RELEVANT REGULATIONS UNDER EMERGING CLIMATE CHANGE

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Abstract

Agricultural products possess on developed while creation assets are reduced. Expand climatic variability present in further problems and arable requires a change of the creation basis to make it more profitable products and the ecological impression. Such a change requires framework wide activities and impressive changes in administration, approaches, and organizations. On this affection, we studied if existing Climate-Smart Agriculture (CSA) can upgrade variation to and moderation of climate change and large food security in India. We found that CSA can considerably contribute towards climate change transformation, alleviation, and food security. Mainstreaming CSA rehearses into advancement arrange through CSVs would make common advantages by create confirmations dependent on CSAs at nearby level, in this way add to the plan of local adaptation plans of action (LAPA) and further feed data into state and public activity plans on climate change. Thus, we can propose to standard CSA into advancement organize.

Keywords: CSA, CSV, LAPA, and climate change.

Introduction

The natural effects of fulfill food expand request will be additionally annoyed by climate change. Changes in water accessibility, the recurrence and force of outrageous occasions, ocean level ascent and salinization, and irritations in environments will all significantly affect agrarian creation (FAO, 2013). The FAO's Food Price Index, which tracks monthly changes in worldwide

costs of regularly exchanged food products and which was delivered, arrived at the ~113.3 focuses in January, with a 4.3 % expansion from December 2020 and July 2014 (FAO, 2021). Climate change impacts farming creation diversely in various zones, with a diminished of creation in tropical and subtropical territories and an expansion in mild zones. Subsequently, it is required to affect more ineffectively weak creating locales with generally lower specialized and monetary ability to react to these dangers. There is proof of the adverse effects of climate change on the yield of cereals and different harvests with variable extents in assorted ecologies. In India moderate expansion in temperature will considerably affect *Oryza sativa*, *Triticum*, and *Zea mays* yield (Aggarwal and Rani, 2009; Aggarwal *et al.*, 2010). For instance, in 2004, because of high temperatures, the wheat crop developed 10–20 days rather in India, prompting a deficiency of over 4,000,000 tons of wheat (Samra and Singh, 2004). Yield creation is adversely affected by expanding water shortage, regular floods, heat pressure, dry spells, and declining natural carbon content in the soil (Singh and Pathak, 2014).

Lobell *et al.* (2012) evaluated from northern India show that wheat creation will confront critical misfortune because of high temperatures. Almost certainly, over half of the Indus-Ganga Plains (IGP) may get inadmissible for wheat because of expanded heat-stress by 2050 (Ortiz *et al.*, 2008). Climate change quickens degradation measures in effectively tarnished conditions and prompts obscure communications and criticism in the perplexing snare of connections among social, natural, food, and monetary systems (Ericksen *et al.*, 2009; Lobell *et al.*, 2011). Choices range from a basic change in administration, *i.e.* a change in planting date to get away from the effect of climate change on the editing systems (Aggarwal *et al.*, 2018).

Climate-Smart Agriculture (CSA) arranged and usage feasible agricultural practices to build the strength of agribusiness to environment changeability through better transformation to climate change and reduce global warming (Lipper *et al.*, 2014). CSA incorporates the rural practices that reasonably expand efficiency, upgrades strength, and ozone-depleting substance outflows, subsequently added to the accomplished of public food security and improvement objectives in a harmless to the ecosystem way (Neufeldt *et al.*, 2013). Both the requirement for agricultural systems logicalized to change environment and moderate GHG emanation from farming, CSA expands on the drawn-out perspective of improvement through feasible agribusiness (Lipper *et al.*, 2014). Accordingly, the need to incorporate climate change into the arranged and uses of economical agribusiness (Campbell *et al.*, 2014).

In India, agriculture production takes care of 17.5% of the worldwide population with just 2.4% of land and 4% of water assets available to it (NAAS, 2013). Worldwide agricultural exploration associations in India have started a few projects supporting CSA. For instance, ICAR has begun an organization project called National Innovations on Climate-Resilient Agriculture (NICRA, <http://www.nicra-icar.in/>). Essentially, in 2011, the CGIAR research program on CCAFS has started a program called Climate-smart village (CSV) in South Asia. All things considered, CSA needs better resolution into the improvement approaches and plans for compelling execution and economical effect at scale.

CONCEPTUAL STRUCTURE OF CSA AND CSV

CSA utilized by this examination and how CSA rehearses address the creative challenges that arose because of climate change and the second layouts the structure of CSVs with possible linkages between innovation, strategy, various institutional strategies, and instruments for out-scaling and up-scaling of CSA rehearses (Aryal, 2020).

Climate-Smart Farming

The CSA incorporates a few arrangements of intercessions, for example, water-smart agriculture, weather-smart, nutrient-smart, carbon and energy-smart, and knowledge-smart activities (Aggarwal *et al.*, 2013).

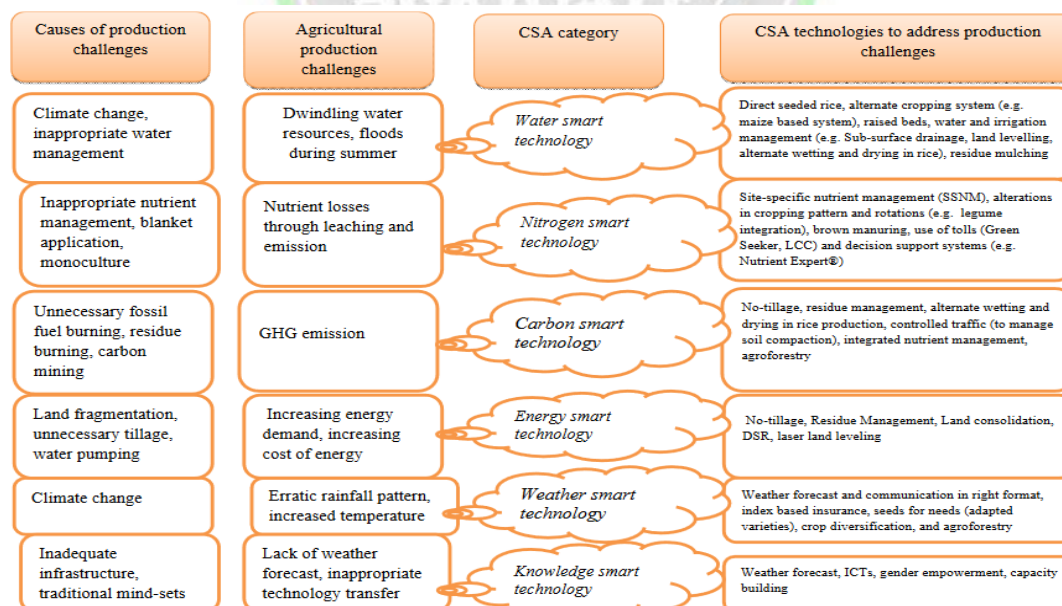


Figure 1. Production challenges in the Indus-Ganga Plain and corresponding CSA technology [Source: Adapted and improved from CCAFS South Asia and Aggarwal *et al.*, (2013)]

Mediations that work in one area may not be relevant in another. The farmers produce a harvest in a framework, testing and assessment of any innovation ought to likewise be finished contemplating the entire framework. Nonetheless, the institutional and administration view at the neighborhood level should be very much coordinated into it while these are the most critical issues as indicated by the new survey of CSA by Dinesh *et al.* (2015)

Climate-Smart Villages

CSV is an institutional way to test, execute, alter and advance CSA at the nearby level and to improve farmers' capacities to adjust to climate change, oversee environmental dangers and assemble strength. The CSV embraces an arrangement of intercessions that cover the full range of farm. The nearby level unit can be characterized regarding the local area or village or group of villages. In south Asia, CCAFS considers 'village' as a neighborhood unit to execute its CSA and consequently, a village where one or a few of the CSAs are tried/reified is known as a CSV. CSV is a site where analysts from public and global associations, individuals from farmers' cooperatives, nearby government, local area pioneers, private area associations (Aryal *et al.*, 2015a). The thought behind CSVs was to advance between focus cooperation and collaborations for tending to food security and the difficulties of climate change by utilizing these villages as learning stages. In 2011, CSVs were guided in two conditions of India: Karnal area of Haryana state and Vaishali locale of Bihar state.

CLIMATE-SMART AGRICULTURE AND CLIMATE-SMART VILLAGES IN INDIA

Many of these practices have been proved to be resilient to climatic extremes, productive, and have low environmental footprints (Aryal *et al.*, 2016; Sapkota *et al.*, 2018). Along with air pollution and its associated health impacts, the practice of residue burn has several negative impacts on agricultural sustainability, such as a reduction in soil fertility and the need for more groundwater for irrigation (Tallis *et al.*, 2017). The state governments along with the private sector organizations have realized the need for CSVs for sustainable agriculture and are joining hands to scaling out CSVs in India (Pandey and Pant, 2017). Also, it is assessed that just about 20 million ha of inundated rice fields will experience the ill effects of some level of water shortage (Lampayan *et al.*, 2015). Therefore, practices that increase water productivity will have significant climate-change adaption potential for all land production systems.

Conclusions

Our examined that current CSA, whenever objectified at scale, can considerably add to environmental change variation, GHG relief from agribusiness, and food security. This essentially improves asset use proficiency, consequently, add to farming supportability. Likewise, a few states like Haryana, Punjab, Bihar, and Maharashtra have begun recognizing the reasonable significance of CSA and have started endeavors to standard CSA through the usage of CSV in their states. Sometimes, the financial advantages of progressing to CSA may not be adequately huge to animate selection, especially for smallholder ranchers. Thusly, the public authority needs to devise a few impetuses to support such change. Regardless of public and global activities for CSA, neighborhood-level organizations in India actually should be reinforced to advance CSA rehearses. This demonstrates a requirement for reinforcing coordinated efforts between global horticultural examination associations and public accomplices.

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CYTOPLASMIC POLYHEDROSIS VIRUS (CPV) IN SILKWORM

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Abstract

Cytoplasmic Polyhedrosis Virus (CPV) is a significant viral disease affecting silkworms, leading to 20–30% crop losses and reduced silk yield, particularly in India's warm, humid silk-producing regions. The virus infects the midgut, causing lethargy, reduced appetite, diarrhoea, and poor cocoon formation. Transmission occurs through contaminated mulberry leaves, unsanitary conditions, overcrowding, environmental stress, and vertical inheritance. Effective management includes strict hygiene, clean feeding, isolation of infected batches, environmental control and use of resistant silkworm strains. Advanced technologies like RNA interference and CRISPR offer promising solutions. Integrated approaches, farmer awareness, and early detection are essential for sustainable sericulture and economic stability.

Introduction

For centuries, silk revered as the "queen of textiles" has symbolized luxury, elegance, and cultural heritage. In countries like India, sericulture is more than just an industry—it is a lifeline for millions of rural families, providing employment and economic support. However, this fragile sector faces numerous challenges, with silkworm diseases posing some of the most serious threats. Among them, Cytoplasmic Polyhedrosis Virus (CPV) stands out as a particularly destructive force, responsible for 20–30% of crop losses annually. This viral infection primarily targets the midgut of silkworms, leading to symptoms such as lethargy, poor appetite, diarrhea, and weak cocoon formation. CPV is especially prevalent in India's key silk-producing regions

like Karnataka, Andhra Pradesh, Tamil Nadu, and West Bengal, where warm, humid conditions favor its spread. In this article, we delve into the impact of CPV on silkworm health and silk production, exploring its symptoms, modes of transmission, and strategies for prevention, to better understand the challenges faced by sericulturists and the urgent need for effective disease management.

Causes for the outbreak of CPV disease

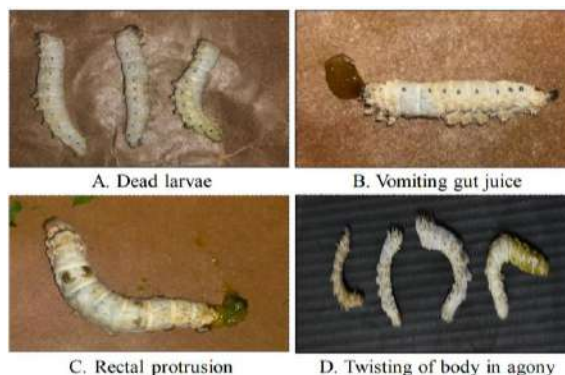
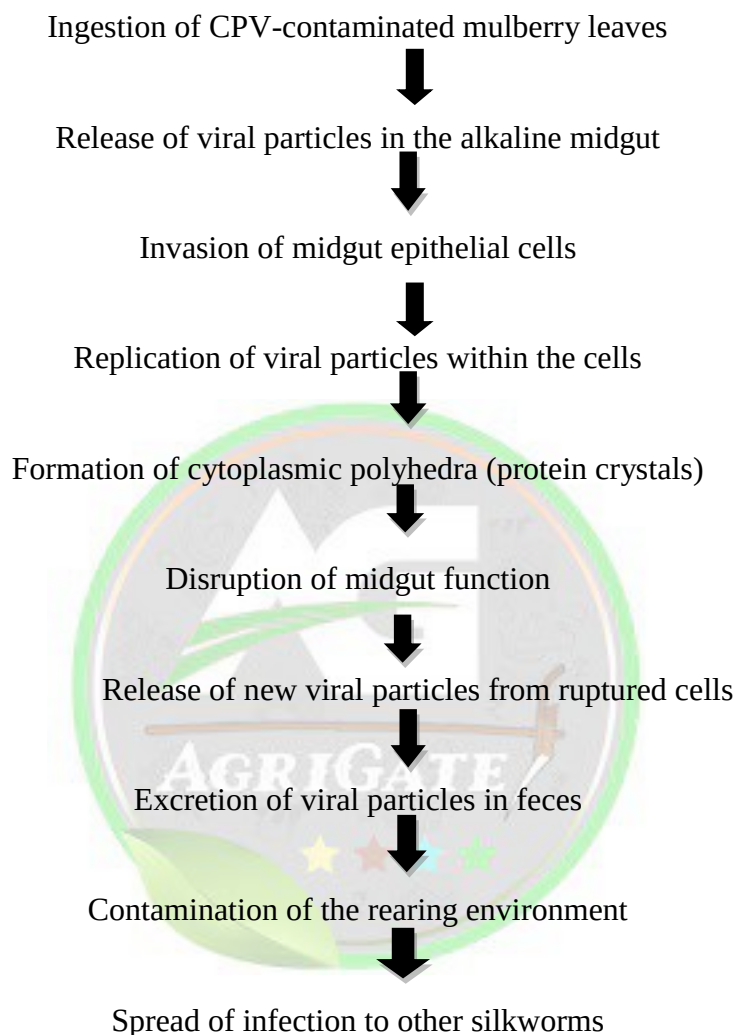
Cytoplasmic Polyhedrosis Virus (CPV) infects through the consumption of polluted mulberry leaves, which serve as the main food source for silkworms and ingestion of contaminated leaves, leading to infection. Environmental pollution also plays a significant role in the virus's transmission. Contaminated water, dirty rearing conditions, and infected silkworm waste can spread the virus throughout the rearing area, further infecting fresh mulberry leaves. Poor sanitation practices such as reusing rearing trays, tools, or equipment without proper disinfection allow the virus to persist and spread. Overcrowded rearing facilities increase the risk, as close contact between silkworms accelerates transmission. Additionally, environmental stressors like sudden changes in temperature and humidity can weaken the silkworms' immune systems, making them more vulnerable to infections. A lack of awareness among farmers about proper rearing methods and disease prevention contributes to the accidental spread of CPV. Furthermore, the virus can be passed from infected female moths to their offspring through eggs, a process known as vertical transmission, allowing CPV to persist across generations.

Symptoms of CPV disease

Infected silkworms exhibit several distinct symptoms that indicate disease progression. Initially, larvae show sluggishness, becoming lethargic and inactive, accompanied by a noticeable loss of appetite. They may stop feeding altogether or consume very little. Diarrhea and vomiting are common, marked by the expulsion of semi-solid, whitish fecal matter and gut juice. As the condition worsens, larvae exhibit stunted growth, lagging behind in development, and may show a disproportionate head where the head becomes large and translucent while the body appears shrunk. A chalky white midgut and frequent discharge of whitish, semi-solid feces further indicate internal infection. Affected larvae often transform into smaller pupae than normal, and adult moths emerging from them show reduced egg-laying capacity and a shortened lifespan. Changes in the anal region, such as solidification and rectal protrusion, may also occur. In some cases, symptoms extend into the adult larval stage, where the thorax turns slightly

transparent, the body undergoes atrophy, and vomiting and diarrhea persist. These signs collectively indicate serious health deterioration in infected silkworms.

Route of infection:



Management

- ❖ Regularly disinfect tools and trays with bleach/formalin.
- ❖ Properly dispose of dead larvae and infected waste.
- ❖ Feed only uncontaminated leaves and avoid leaves from infected or nearby rearing areas.
- ❖ Separate infected batches to prevent spread.
- ❖ Monitor and remove visibly infected silkworms.
- ❖ Maintain optimal temperature and humidity.
- ❖ Avoid sudden environmental changes.
- ❖ Use CPV-resistant or genetically improved strains.
- ❖ Conduct regular health checks and immediate removal of infected individuals.
- ❖ Provide training on disease management and hygiene.
- ❖ Promote awareness of early intervention.
- ❖ Combined management of hygiene, environment control, and use of resistant strains.
- ❖ Regularly update practices with new research

Conclusion

Strict hygiene procedures, the supply of hygienic mulberry leaves, the isolation of contaminated batches, environmental control, and the use of disease-resistant silkworm strains are necessary for the effective management of CPV. Fighting the virus requires early detection and farmer education may reduce the crop loss, and protects the livelihoods of millions of people depend on the silk business.

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PEBRINE DISEASE IN SILKWORM

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Abstract

Pebrine, caused by *Nosema bombycis*, severely impacts sericulture by infecting silkworms at all life stages, causing poor hatching, growth delays, moth deformities, and erratic egg-laying. Historically, outbreaks reduced silk yields by 30–40%. While *Bombyx mori* faces threats from various pathogens, pebrine remains highly destructive detected during 19th-century and led to sericulture decline in France. Traditional microscopy-based diagnosis often failed to curb its spread, but modern PCR-based methods improve the early detection. Effective control requires strict hygiene, routine testing, destroying infected stock, and using certified disease-free eggs. Combining advanced diagnostics with prevention strategies can minimize losses and secure sustainable silk production. This review summarizes the key aspects of microsporidiosis, discusses current challenges, and proposes strategies to safeguard the future sericulture against persistent disease.

Introduction

The mulberry silkworm *Bombyx mori* is highly susceptible to pathogens, particularly microsporidiosis caused by *Nosema bombycis*, called as pebrine, marked by pepper-like spots on larvae can be chronic or severe, causing major losses in the silk industry. Over time, diverse microsporidian strains have complicated the disease control, with outbreaks historically affecting sericulture's growth. The name pebrine was coined De Quadrefages (1860), the pathogen was initially called "Hematozoid" before Nageli classified it as a protozoan. Louis

Pasteur identified its transovarial transmission and proposed prevention methods, while Balbiani confirmed its protozoan nature. In India, pebrine emerged in Kashmir in the late 1800s, spreading to Mysore and Madras by the early 1900s and severe outbreaks occurred in 1925–1930 and 1991–1992 caused massive crop failures with economic losses exceeded Rs.200 crores.

Causes of Infection

The primary cause of pebrine disease is transovarial transmission, where the pathogen *Nosema bombycis* is passed from an infected female moth to her offspring through eggs, ensuring the disease persists across the generations. Silkworms can also contract the disease by ingesting spores from contaminated mulberry leaves or the rearing environment, as these spores are highly resistant and long-lasting. Using infected eggs or larvae for rearing further spreads the disease to healthy populations. Poor hygiene, such as unclean tools or equipment, and cross-contamination from handling infected and healthy silkworms without precautions also facilitate its spread. Wild insects can act as carriers, introducing the pathogen into rearing areas and environmental factors like poor nutrition, overcrowding, and unfavorable conditions weaken silkworms' immunity, making them more susceptible. Inadequate disease management practices, such as failing to test mother moths or improperly disposing of infected larvae, further exacerbate the problem. These factors make pebrine a persistent challenge in sericulture, requiring strict hygiene, regular monitoring, and the use of disease-free stock to prevent outbreaks.

Routes of Infection

Nosema sp., the cause of pebrine disease in silkworms, spreads through both vertical (transovarian) and horizontal (oral) transmission. Vertical transmission occurs when the pathogen passes from an infected parent to offspring via eggs, while horizontal transmission



happens when silkworms ingest spores from contaminated mulberry leaves or the rearing environment. In transovarian transmission, the pathogen infects 4th and 5th instar larvae, invading ovarian cells and often causing egg death. If infection occurs during embryo formation, development halts, leading to egg mortality. Within rearing trays, infected silkworms excrete spores through feces or epicuticles, contaminating the environment and infecting healthy larvae. Primary contamination occurs when I and II instar larvae are infected, with spores excreted in later stages. Secondary contamination happens when healthy larvae ingest these spores, often developing into moths that lay infected eggs. Young or starving larvae are highly vulnerable, with high mortality rates. Secondary contamination drives the spread of pebrine, making it a persistent challenge. Effective control requires strict hygiene, regular monitoring, and disease-free stock to break the infection cycle.

(Source of Image: Google)

Symptoms

The symptoms of pebrine disease in silkworms vary depending on the stage of infection and the developmental stage of the silkworm. The disease manifests differently in the egg, larval, pupal, and moth stages. In the egg stage, infected eggs exhibit poor production numbers, often piling up of eggs one over the another due to a lack of adhesive fluid, which reduces their ability to stick to the egg sheet. The eggs may also show irregular shapes, a higher proportion of unfertilized or dead eggs, and poor or irregular hatching patterns.

During the larval stage, infected larvae display a range of symptoms, including poor appetite, retarded growth, and uneven development, leading to larvae of unequal sizes. The larvae may appear paler, translucent, and sluggish, with wrinkled skin and irregular moulting. They often lose their appetite, vomit gut juice, shrink in size, and become undersized. The gut of infected larvae becomes opaque, and the silk gland may develop white pustules. Black, pepper-like spots may appear on the skin, and moulting is often incomplete. Dead larvae remain rubbery for an extended period before turning black.

In the pupal stage, infected pupae become flabby, swollen, and have a lusterless, softened abdomen. Irregular black spots may appear near the wing rudiments and abdominal area. Severely infected pupae often fail to metamorphose into adult moths. In the moth stage, symptoms include delayed and erratic emergence, clubbed wings, and distorted antennae. Infected moths are typically inactive, fail to mate properly, and lose scales from their wings and

abdominal area easily. Additionally, they lay eggs in a clumpy manner, further spreading the disease. These symptoms collectively highlight the devastating impact of pebrine disease on silkworms, affecting their growth, development, and reproductive capabilities, ultimately leading to significant losses in sericulture.

Management

To prevent pebrine disease and ensure healthy silkworm egg production, a systematic and scientific approach is essential which includes examining mother moths at egg production centers to avoid embryonic infections, removing and destroying potential sources of contamination like dead eggs, larvae, pupae, and excrement, and maintaining strict hygiene throughout the rearing process. Regular disinfection of facilities and equipment, along with surface sterilization using a 2% formalin solution, is critical. Early detection through standardized inspections of eggshells and larvae at each instar stage is vital. Infected crops in early stages must be destroyed, while cocoons in later stages can be sent for reeling. Eggs from infected moths should be burned immediately. Synchronized rearing practices, regular monitoring, and adherence to seed legislation help minimize risks. Avoiding shared appliances and isolating infected trays further prevent contamination. An integrated approach, including microscopic examination of silkworm seeds and destruction of pathogens at various lifecycle stages, is key to controlling pebrine and ensuring sustainable silk production.

Conclusion

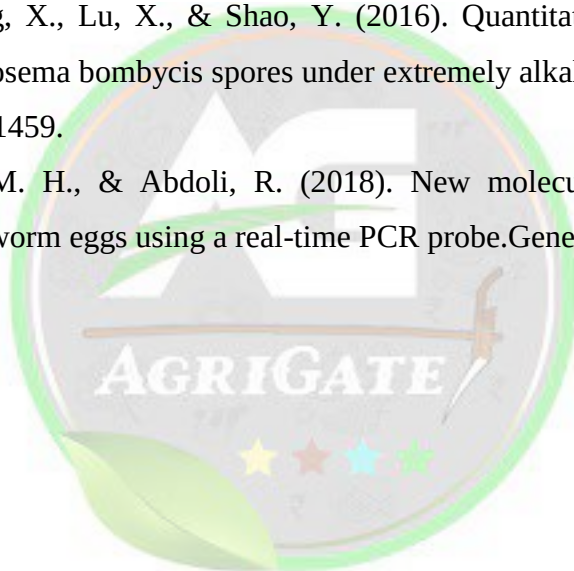
The absence of accurate disease diagnosis in sericulture has led to the severe spread of various virulent diseases, including microsporidiosis, resulting in significant crop losses of 30-40%. Traditionally, microsporidia were identified based on their morphological characteristics using microscopy, a cost-effective and age-old practice that has been in use for centuries. However, the emergence of new and more complex strains of microsporidia has made their identification increasingly challenging, as their spores become visible only 3–8 days after the onset of infection. This delay in detection often allows the disease to spread unchecked. To address this issue, there is an urgent need to adopt advanced biotechnological approaches, such as PCR-based DNA marker technology. This method enables the early detection of microsporidian infections in silkworms, providing sericulture researchers and farmers with a powerful tool for effective disease management. By facilitating timely intervention, the modern techniques can help prevent crop losses caused by such virulent pathogens, ensuring sustainable sericulture



practices and safeguarding the industry's future.

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WHITE MUSCARDINE DISEASE IN SILKWORMS: A SILENT THREAT TO SERICULTURE

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Abstract

White Muscardine disease is caused by the fungus *Beauveria bassiana*, poses a significant threat to sericulture, particularly in regions like India, where silkworm farming is a vital economic activity. This disease thrives in warm, humid conditions, leading to high mortality rates among silkworms, which in turn results in substantial economic losses. The infection progresses through four stages, starting with sluggishness, poor feeding, and culminating in the mummification of larvae covered with white fungal growth. Transmission occurs through direct contact, airborne spores, and contaminated equipment. Effective management requires a multifaceted approach, including strict hygiene practices, environmental control (temperature and humidity regulation) and chemical treatments (e.g., formalin, bleach powder). Additionally, breeding of resistant silkworm breeds can help to mitigate the impact of the disease. Early detection and comprehensive management strategies are crucial for sustaining sericulture and ensuring the success and profitability of silk production. Future research should focus on development of disease-resistant strains and refining management practices to combat this persistent threat.

Introduction

Silkworms (*Bombyx mori*) are commercially reared for silk production, with India being the second-largest producer, led by Karnataka. Sericulture plays a vital role in rural employment, and high-quality silk production depends on factors like temperature, humidity, nutrition, and breed selection. However, diseases like white muscardine disease poses a significant threat to

silkworm rearing caused by the fungus, *Beauveria bassiana*, spreads rapidly in humid conditions, infecting silkworm and leading to high mortality rates. Affected larvae become lethargic, stop feeding, and develop white fungal growth, eventually mummifying. This disease can cause severe economic losses if not managed properly. Effective disease control through hygiene maintenance, humidity regulation, and early detection is crucial for sustaining sericulture and ensuring profitable silk production.

Causes and outbreak of disease

The spread and occurrence of white muscardine disease correlates with environmental settings and other agricultural practices. This fungal infection thrives well in warm and moist conditions, which makes the rearing of silkworms very prone to it.

- Increased moisture and heat: The humidity sustaining conditions of over 85% and 25°C - 30°C temperature range helps *Beauveria bassiana* to grow and thrive. Greater moisture within the atmosphere makes the post monsoon and monsoon seasons even more dangerous.
- Poor air flow: In rearing rooms where there is little airflow, excess humidity can easily build up. This excess humidity causes mould to thrive within the rooms.
- Infested equipment for Rearing: Breeding trays, the walls and even the floors of silkworm farms have the potential to harbour fungal spores for great spans of time. These spores make reinfection onto other worms very easy if proper cleanliness is not maintained.
- Diseased silkworms: Silkworms are capable of spreading the disease to other silkworms through physical contact, food consumption, and even through the air.
- Unhygienic Habits: Farmers who do not follow proper guidelines for disinfecting the breeding area allow for fungal spores to spread freely within a silkworm's breeding habitat.

To mitigate the devastating impact of white muscardine Disease, it is imperative that silkworm farmers adopt a comprehensive approach that addresses these key contributing factors. By putting a strong emphasis on controlling environmental factors, ensuring top notch hygiene standards and really living by principle we can keep our silkworms healthy and productive.

Mode of Transmission

It is mainly transmitted by

- Direct contact with diseased silkworms;

- Airborne spore dispersion;
- Contaminated rearing trays, tools, and clothing;
- Spores found in dust and debris inside the rearing house.

Symptoms

Early diagnosis of a White Muscardine Disease is a strong leverage for stopping the flow of infection. The disease has four stages: The infected silkworms have slow movement, sluggish behaviour, and poor feeding. Some of them may show some discoloration. The white fungal growth appears on the body, mainly at the intersegmental regions. The affected silkworms become more relaxed and possibly cease feeding. The entirety of the infected silkworm body is covered by a woolly white fungal mass and larvae become rigid and mummified during the advanced stage. Finally, the cadaver changes into a dry, powdery mass as the spores develop, being scattered into the environment for infecting other silkworms.

Life cycle

The life cycle of *Beauveria bassiana* plays a crucial role in how the disease infects silkworms. It includes:

- The fungal spores stick to the surface of silkworms when they touch them.
- After attaching, spores start to grow and release enzymes that break down the cuticle. This allows the fungus to enter the host's body.
- The fungus spreads through the silkworm's haemolymph using available nutrients and disrupting normal body functions.
- After the silkworm dies, the fungus keeps growing on its body. It forms white, thread-like structures and begins to make spores. These new spores can then infect other hosts.
- The whole cycle takes 4 to 6 days, depending on the environment. Damp conditions speed up growth, which shows why it's important to control outbreaks early.

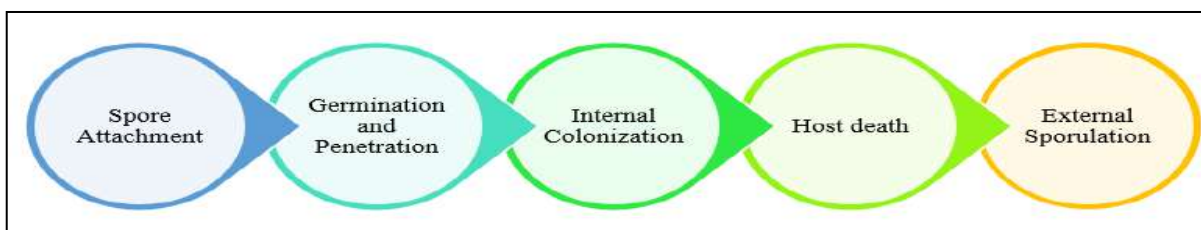


Fig. 2 Life Cycle of *Beauveria bassiana*

Management

To keep White Muscardine Disease in check, it is essential to have a well-rounded plan. This plan should mix good cleaning habits control of the environment, and the use of chemicals and living things to fight the disease.

- Cleaning the rearing trays and tools often with 2% formalin or bleach powder (5% mix). Getting rid of sick silkworms, the right way by burning them or burying them deep so the disease doesn't spread.
- Cleaning and disinfecting the rooms where you raise silkworms before and after each batch.
- Putting on protective clothes when you handle silkworms to avoid spreading germs.
- Keep the temperature just right (22–26°C) and the dampness low (under 80%).
- Spreading of lime powder on the floor and walls to soak up extra water and slow down fungus growth.
- Spray 0.3% formalin or 1% bleach powder mix in the raising area to kill fungus spores.
- Dust slaked lime (Ca(OH)_2) or 0.5% Bordeaux mix in the raising bed to stop fungus from growing.
- Put on anti-fungus agents like Bavistin (carbendazim) in the right amounts.
- Use of disease resistant silkworms to fungal infections.

Conclusion

White Muscardine Disease is a major threat to silkworm producers that leads to significant losses to the silk industry. Under the best conditions, this is a rapidly transmissible disease; once established, it is extraordinarily difficult to control. Farmers need to focus more on maintaining cleanliness, changing the environment, and using effective chemical control options to mitigate its impacts.

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GREEN MUSCARDINE DISEASE IN SILKWORM

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Abstract

Green Muscardine is a deadly fungal disease of mulberry silkworm, *Bombyx mori* L., caused by the fungus *Metarhizium anisopliae*. It is a major threat to sericulture industry, causing 30-45% crop loss every year in India and other silk producing countries. It is more prevalent during rainy and winter seasons due to high humidity and moderate temperature. Environmental factors like poor hygiene, overcrowding, inadequate ventilation and high humidity favour the disease outbreak. Control measures include environmental regulation, use of antifungal agents like formalin and strict hygiene practices like regular cleaning and disinfection. Breeding and promoting disease resistant silkworm strains, especially multivoltine and certain Thai and Japanese breeds will be a long-term solution to reduce the susceptibility. Integrated disease management and education to the farmers is the key to minimize the losses.

Introduction

Silkworms are economically significant insects, primarily reared for silk production since long period from 3000 BC. Silkworm productivity is often threatened by various diseases, among which fungal disease is more prominent, collectively called mycosis. Every year the disease causes 30-45% loss in the sericulture industry in India and other sericulture countries. Usually, fungal diseases are prevalent throughout the year especially in temperate regions due to low temperature and high humidity. Green Muscardine, a fungal disease caused by *Metarhizium anisopliae*. This entomopathogenic fungus affects silkworm populations, leading to significant losses in sericulture. It causes crop loss of more than 20% in the rainy season, followed by winter

(11-15% loss) and summer season (Reddy and Rao, 2009). The disease is characterized by external fungal growth that turns infected larvae to green, ultimately causing mortality. Understanding and early identification of green muscardine is vital for controlling it in silkworm rearing practices and maintaining productivity. Good hygienic rearing practices help to keep away from this kind of diseases and contribute for successful cocoon crop production.

Metarhizium anisopliae was first discovered by Metchnikoff in 1879 as a parasite of the wheat cockchafer, *Anisoplia austriaca*. In 1880, Metschnikoff further found that the fungus was a parasite of the sugar beet curculio, *Cleonus punctiventris*.

He said that the parasite produces an epizootic disease of the insects mentioned and believes it possible to use the disease economically to affect the destruction of pests by sowing the spores. Green Muscardine caused by *Spicaria prasina* in silkworms is called Japanese Green Muscardine, which belongs to Class Hyphomycetes and Family Moniliaceae. *Metarhizium rileyi* is species of Green Muscardine found in China and became threat to in sericulture industry (Zhang et al 2016). These fungus causes disease in insects, which helps in economic control of insect pests but also causes disease to economically important insects too.

Etiology of *Metarhizium anisopliae*

Green Muscardine belongs to the family Clavicipitaceae and the order Hypocreales. Two forms are recognized in green muscardine, major form is more virulent with long spore and minor form is a small spore. This fungus is also characterized by its ability to infect the silkworms (*Bombyx mori* L.), where it can spread quickly through the rearing environment. Outbreak of disease is due to the improper spacing, bed cleaning by hand without sanitation, irregular cleaning of bed, non-maintenance of optimum temperature and relative humidity during winter and rainy season, improper disposal of litter and bed refuse, irregular feeding and starvation and mechanical wounds to the silkworms.

LIFE CYCLE OF THE *Metarhizium anisopliae*

1. Infection Stage

The fungal spores (conidia-colorless to slight green, globular or oval in shape) of *M. anisopliae* are transmitted to silkworms through direct contact or contaminated surfaces. These spores are highly resistant to environmental stresses and can persist in the rearing environment for a long time.

2. Germination and Penetration

Once the spores come in contact with the silkworm's cuticle, they adhere and start germinating, forming a germ tube. Under favorable environment, the conidium germinates within 8-10 hours of coming in contact with the body of the silkworm. The fungus then penetrates the insect's body through enzymatic degradation of the cuticle by secreting chitinase enzyme. Germ tube develops as vegetative hyphae by multiplication process (Hyphae- Aseptate, hyaline, smooth walled bearing group of lateral cells). The ability to breach the insect's outer defences makes the fungus particularly effective as a pathogen.

3. Proliferation and Sporulation

After entering the host, *M. anisopliae* proliferates inside the silkworm, feeding on its tissues and releasing toxins that cause systemic infection. The fungus eventually fills the insect's body, leading to the death of the silkworm. The final stage involves the fungus emerging from the dead body i.e., the vegetative hyphae come out of the skin to form aerial hyphae. Which bears innumerable conidiophores, it sporulates and produces a small branch which bear one or two conidia. They look like a green layer, hence the name "Green Muscardine."

Green Muscardine spreads mainly through conidial spores that contaminate the rearing environment. These spores can be transmitted through air, infected rearing equipment, the bodies of infected silkworms, mummified larvae, and Dead caterpillar from mulberry fields. Human handling can also contribute to the transmission of the fungal spores between batches of silkworms

Factor causing the outbreak of disease

Humidity

The fungus thrives in high humidity environments, more than 85%. Silkworm rearing houses with poor ventilation or improper humidity control provide ideal conditions for the growth and spread of *M. anisopliae*.

Temperature

Moderate temperature ranges between 20–28°C is conducive to fungal growth. Under these conditions, the spores can germinate quickly and infect silkworms more effectively.

Poor Hygiene

Contaminated rearing trays, uncleaned rearing environments, and improper disposal of dead silkworms can lead to the persistence and proliferation of fungal spores.

Dark light and moist condition favour the growth of spores.

Symptoms

Initial Symptoms:

Infected silkworms may show behavioural changes such as sluggish movement, inactiveness and loss of appetite. The larvae often become lethargic, slow down their feeding and Loss of skin elasticity.

In serious case the silkworm larvae vomit fluid, has diarrhoea and dies. Larva wont decay but remain hard since the fungus secretes double oxalate crystals of ammonium and magnesium.

Visible Signs:

Initially, the dead body of the larva appears white in colour. Dark brown irregular lesions appear on the ventral, dorsal and lateral sides. In the later stages, A green fungal growth appears on the surface of the silkworm. The entire body, except the head, will be covered with green powdery material and the larvae look like dry green stick. The green powdery appearance is a clear indication of the presence of the fungus sporulating on the insect's surface. The silkworm's body finally becomes hardened, shrivelled, and stiff. During pupal stage, Infected pupal thoracic region appears shrunk and the abdomen wrinkled. The pupae are hard, lighter, mummified and greenish colour. During moth stage, the body is hardened and the wings fall off easily. Infected eggs are paler and conidia may be seen on the egg surface. The diseased eggs not viable and do not hatch.

Mortality:

The infected silkworms die rapidly within 2-3 days of infection, especially when environmental conditions (high humidity and moderate temperatures) are favourable for the fungal growth. After death the soft corpse gradually hardens. After 10-15 days white mycelia



Silkworm cadavers infected with Green Muscardine

produce fresh green conidia and worm looks green. A mass outbreak in rearing conditions can lead to high mortality rates, reducing the overall yield of silk.

Control and management strategies

Effective management of Green muscardine involves a combination of good hygiene, environmental control, and preventive measures. Regular cleaning and disinfecting of silkworm rearing trays, equipment, and rearing rooms are essential to minimize fungal spore contamination. Laying's are surface sterilized with 2 % formalin. As a preventive measure, managing of low temperature and high humidity in rearing room plays important role in managing fungal diseases. Regulation of the air circulation without causing suffocation to rearing environment. Usage of heaters (electrical or charcoal) to raise room temperature, Dusting of dry slaked lime powder on the rearing room floor, which removes high moisture content in rearing bed as well as act as bed disinfectant.

Dusting of dry slaked lime powder on the silkworms, after bed cleaning or before feeding in the morning. Avoiding the over feeding which leads to increase in humidity. So, it is suggested to feed only the quantum of mulberry leaves, the larvae consume during the feed period. Avoid accumulation of silkworm waste and faeces in the bed. Feed comparatively more mature leaves than the leaves fed during normal period. Using of antifungal agents, Labex, Formalin chaff, Bavistin 0.4%, kavach, and Dithane M-45 or Captan with levigated china clay (Kaolin) to reduce the fungal spore loads. Rearing of resistant breeds, mulvotines are less susceptible than bivoltine breeds. PM, C.Nichi & RD, are less susceptible which can help to reduce the impact of Green Muscardine in large-scale silk production.

Conclusion

Green Muscardine as a fungal disease remains one of the primary threats to sericulture industry. The economic impact of this disease in sericulture is significant. It can cause significant crop loss, particularly during the rainy and winter seasons. The disease can affect both the cocoon and egg production stages. Infected silkworms produce little to no silk, and mass outbreaks can destroy entire batches of silkworms. The quality of silk produced by infected silkworms is also compromised due to the poor health of the larvae. But with proper environmental management and the application of antifungal treatments, its spread can be controlled.. Even though it is difficult to control after incidence of disease, implementing preventive measures, researches and advancements in sericulture management and educating

sericulturists on disease management will likely continue to reduce the prevalence of green muscardine in silkworm.

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BACTERIAL DISEASES OF SILKWORM

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Abstract

Silkworm rearing is a vital economic activity, yet it faces significant challenges from bacterial diseases, particularly flacherie, which severely impacts cocoon production. Bacterial flacherie, caused by several pathogens such as *Streptococcus faecalis*, *Serratia marcescens*, and *Bacillus thuringiensis*, manifests through symptoms like larval flaccidity, vomiting and stunted growth. These infections are exacerbated by stress factors such as poor nutrition, improper rearing conditions, and inadequate hygiene. Bacterial diseases in silkworms are categorized into bacteremia, septicemia, and toxicosis, each with distinct pathological effects. Effective management strategies include disinfection of rearing environments, provision of high-quality mulberry leaves, optimal temperature and humidity control, and the use of antibiotics like erythromycin and tetracycline. Prophylactic measures, such as enriching mulberry leaves with gentamycin or ampicillin, have proven effective in reducing disease incidence. Maintaining hygienic, well-ventilated, and stress-free rearing conditions is essential for minimizing bacterial infections and ensuring successful silkworm cultivation and cocoon yield.

Introduction

Silkworm rearing is a highly lucrative occupation for numerous sericulturists across the country. The success of silkworm cultivation hinges on several factors, including the quality of mulberry leaves, optimal temperature and humidity, adequate larval spacing, proper ventilation, and protection from diseases and pests. However, silkworm are often threatened by infections

caused by bacteria, viruses, fungi, microsporidia and other pathogens, which significantly hinder successful cocoon production. Diseases such as grasserie, flacherie, muscardine, and pebrine are primarily caused by these pathogens. Flacherie, in particular, is triggered by both microbial and non-microbial agents, with microbial flacherie resulting from bacterial and viral infections. Bacteria can act alone or in conjunction with viruses, leading to widespread disease outbreaks. While countries like China and Japan experience relatively lower silkworm crop losses due to diseases, India faces more severe impacts, significantly affecting the economic returns of sericulturists. In Karnataka, bacterial flacherie accounts for 57.22% of total disease occurrences, as determined through microscopic analysis of haemolymph and midgut smears (Samson *et al.*, 1990). Bacterial infections often cause high mortality rates, particularly during the moulting stage and when larvae are preparing to spin, with the highest mortality observed among fifth-instar silkworm larvae.

Bacterial Diseases in Silkworm

In 1870, Pasteur identified that a coccus and bacillus bacteria were responsible for causing flacherie in silkworms. Subsequent research by various scientists revealed that multiple bacterial species contribute to bacteriosis in silkworms. For instance, Cuboni and Garibini (1890) attributed flacherie to *Bacillus cubonianus*. In Japan, the causative agent of Sotto disease was identified as *Bacillus sotto* (Iwashita, 1902), now known as *Bacillus thuringiensis* var. *sotto*.

Bacillus megaterium, *Bacillus ellenbachii*, *Serratia marcescens*, *Bacillus bombysepticus*, *Bacillus bombycoides*, *Streptococcus bombycis*, *Bacillus mucoides*, *Bacillus latrosporus*, *Bacillus cereus* var, *Aerobacter cloacae*, *Achromobacter superficialis*, *Streptococcus faecalis*, *Serratia piscatorum*, *Proteus vulgaris*, *Proteus inconstina*, *Proteus morganii*, *Proteus aerobacter*, *Proteus aerogenes*, *Micrococcus flavus*, *Aerobacter cloacae*, *Achromobacter delmarvae*, *superficialis*, *Pseudomonas boreopolis*, *P. ovalis*, and *Escherichia freundii*, *Staphylococcus albus* from infected silkworms.

Flacherie is characterized by the flaccidity of the larval body, with bacterial-induced flaccidity referred to as bacterial flacherie. The symptoms caused by different bacteria are generally similar and nonspecific. Infected larvae lose their appetite, become lethargic, and vomit gut juice. Their growth is stunted, and they turn flaccid. Upon death, the larvae exhibit varying colors depending on the bacterial species involved, eventually rotting and emitting a foul

odor. Based on the site of infection and the pathogenicity of the bacteria, bacterial diseases in silkworms are classified into three categories, Bactremia, septicaemia and toxicosis.

A. Bacteremia

Bacteremia, or bacterial disease of the digestive tract, occurs when bacteria multiply within the gut. These bacteria primarily infect silkworms through the mouth and digestive tract, leading to a chronic form of flacherie. The cephalothoracic region becomes translucent, and in advanced stages, the posterior portion also turns translucent. Infected larvae exhibit symptoms such as loss of appetite, sluggishness, stunted growth, and diarrhea. *Streptococcus faecalis* and *Streptococcus faecium* are the most common bacteria associated with digestive organ diseases in the silkworm *Bombyx mori*. These gram-positive bacteria measure 0.7–0.9 μm in diameter. *Streptococcus faecalis* multiplies over 2–3 days, forming large colonies attached to the larval peritrophic membrane. After six days, the peritrophic membrane dissolves, and the goblet and cylindrical cells become vacuolated. The larvae die as the digestive tract fluid and bacteria pass through the vacuolated midgut epithelium into the hemolymph.

In the digestive tract, the bacteria produce enzymes such as chitinase, lecithinase, and proteinase, which act on the midgut epithelium, allowing the bacteria to enter the hemocoel. Bacterial exotoxins and endotoxins also play a significant role in the invasion of the digestive tract by damaging the gut wall and facilitating bacterial entry into the hemocoel. Infection by *S. faecium* in fifth-instar larvae lowers the gut pH from a range of 8.0–9.5 to 7.5–7.6, creating conditions favourable for most septicemic bacteria.

B. Septicemia

Septicemia in silkworms occurs when septic bacteria invade and multiply within the silkworm body, leading to mortality. Most silkworms affected by this disease vomit gut fluid, and their bodies become soft, shrunken, and swollen in the thoracic region. A high concentration of bacteria is observed in the hemolymph, and the body wall easily ruptures, releasing a foul-smelling fluid filled with bacterial cells. Infected larvae die shortly after infection.

Various bacteria, including *Serratia marcescens*, *Pseudomonas* sp., *Bacillus proteus*, *Bacillus aerogenes*, *Bacillus prodigiosus*, *Bacillus pyocyaneus*, and *Streptococcus* sp., have been isolated from silkworms with septicemia. However, the most common pathogens are *Serratia marcescens* and *Bacillus* sp. In cases of septicemia caused by *Bacillus* sp., the silkworm's body develops a dark greenish tinge on the dorso-thoracic region shortly after death,

which later spreads to the entire body. In contrast, septicemia caused by *Serratia marcescens* results in dark brown spots and a reddish tinge on the larvae after death, eventually covering the whole body. Injection of $6-8 \times 10^2$ bacteria can cause death within 18 hours.

The pathogenicity of orally inoculated *Serratia* leads to high mortality under high humidity, though the mortality rate varies with the bacterial concentration in the feed. Bacterial septicemia in pre-pupal or pupal stages can spoil cocoon quality and reduce grainage productivity. The *Bacillus* species responsible for septicemia are rod-shaped, measuring $1-1.5 \times 3 \mu\text{m}$, with sub-terminal spores and peritrichate flagella. *Serratia marcescens* appears as small rods, $0.6-1.0 \times 0.5 \mu\text{m}$, and is non-sporulating with peritrichate flagella.

While *Serratia marcescens* in the digestive tract is non-pathogenic, it becomes highly pathogenic upon entering the hemocoel, multiplying rapidly and causing acute disease, leading to death within 1–3 days. Septic bacteria can invade silkworms not only through a damaged gut wall but also through wounds caused by injury, rapidly multiplying in the hemolymph. The invasion of *Serratia piscatorum* into the hemocoel is facilitated by the presence of *Streptococcus faecalis* or *Streptococcus faecium* in the larval midgut. These bacteria lower the pH, creating favourable conditions for *Serratia piscatorum* to multiply, invade the hemocoel, and cause fatal septicemia.

C. Toxicosis

Bacterial toxicosis is primarily caused by *Bacillus thuringiensis*, with the common variant being *B.t. var. sotto*. Larvae affected by bacterial toxicosis lose their appetite and become sluggish. The dorsal vessel pulsates rapidly, and the larvae wriggle as if experiencing severe pain. Three exotoxins— α -exotoxin, β -exotoxin, and γ -exotoxin—along with an endotoxin, δ -endotoxin, have been isolated from *B. thuringiensis*. When the larvae ingest the toxin, it dissolves in the digestive fluid and is partially absorbed into the body, causing toxicity which affects the nervous system, leading to convulsions or paralysis. Bacterial toxicosis is categorized into acute and chronic bacterial toxicosis.

Acute bacterial toxicosis

This condition results from ingesting parasporal crystal bodies, known as δ -endotoxin, produced by *Bacillus thuringiensis*. Key symptoms include sudden cessation of feeding, lifting of the head, spasms, tremors, paralysis, distress, sudden collapse, and death. Death can occur within 10 minutes to a few hours. Shortly after death, the corpse becomes hard to the touch, with

the head retracted, giving it a hook-like appearance. Over time, the corpse turns black, rots, and releases a foul-smelling dark brown fluid.

Chronic bacterial toxicosis

This form is caused by ingesting small amounts of *Bt* crystal toxin. Symptoms include reduced mulberry leaf consumption, irregularly shaped feces, occasional vomiting, and muscle paralysis. The thorax and abdominal tip become transparent, and the larvae become motionless. Within 10–12 hours of infection, sluggishness, loss of leg-clasping ability, flaccidity, and death are observed.

MANAGEMENT

1. **Disinfection and Hygiene:** Thoroughly disinfect rearing rooms and equipment before and after each rearing cycle. Maintain **personal** and rearing hygiene to prevent pathogens. Use surface-disinfected eggs and rear early instar silkworms under optimal conditions.
2. **Nutrition and Leaf Quality:** Feed silkworms high-quality, nutritious mulberry leaves, avoiding leaves grown in shade or with excessive nitrogen. Ensure hygienic and favorable rearing conditions to prevent bacterial flacherie.
3. **Environmental Management:** Provide adequate bed space, ventilation, and proper temperature (20-28°C) and humidity control. Avoid overcrowding, wet leaves, and waste accumulation. Incubate eggs at 26°C and 80-85% humidity for robust growth.
4. **Disease Prevention:** Regularly disinfect rearing tools and trays, avoiding cow dung smearing. Remove and dispose of diseased silkworms promptly. Use dry slaked lime to control humidity and pathogens.
5. **Antibiotics and Prophylaxis:** Use antibiotics like erythromycin, kanamycin, and tetracycline to manage bacterial diseases. Enrich mulberry leaves with 0.1% gentamycin or treat with 500 ppm ampicillin during specific instars to prevent flacherie and improve cocoon yield.

Overall, maintaining a clean, well-ventilated, and optimally managed rearing environment is crucial for healthy silkworm growth and disease prevention.

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AGRO-FOREST FOR MAKING HUMAN HABITATS CARBON NEUTRAL – A KERALA PERSPECTIVE

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Abstract

Agroforest for Making Human Habitats Carbon Neutral. Agroforestry systems offer a promising approach to creating carbon-neutral human habitats. By integrating trees, crops, and livestock, these systems can sequester carbon, reduce greenhouse gas emissions, and provide numerous ecosystem benefits. This paper explores the potential of agroforestry to mitigate climate change, enhance biodiversity, and support sustainable livelihoods. We discuss design principles, implementation strategies, and case studies of successful agroforestry projects. The findings suggest that agroforestry can play a vital role in achieving carbon neutrality and promoting resilient, sustainable communities.

Keywords: Agro forest, human habitats, carbon sequestration, Miyawaki model, Kavu models, IOFS models.

Introduction

The earth we live in is inhabited by several organisms which may be living, non living, animals, trees, herbs, plants, birds, insects, creepers, aquatic species, micro – macro organisms so and so forth for thousands of years. This inhabitation on earth is ruled by the most brilliant species – humans' currently. Nature is a broad term which refers to the general realm of living plants and animals. Humans are a part of this broad eco system referred to as nature. Human intervention has altered the eco system and specifically nature. Earth is the only planet known to support life, and its natural features are the subject of any fields of scientific research. Its most prominent climatic features are its two large polar regions, two relatively narrow temperate

zones, and a wide equatorial tropical to sub-tropical region. Precipitation varies widely with location, from several metres of water per year to less than a millimetre. 71 % of the Earth's surface is covered by salt-water oceans. The remainder consists of continents and islands, with most of the inhabited land in the Northern Hemisphere. The atmospheric conditions have been significantly altered from the original conditions by the presence of life-forms, which create an ecological balance that stabilizes the surface conditions. Despite the wide regional variations in climate by latitude and other geographic factors, the long-term average global climate is quite stable during interglacial periods and variations of a degree or two of average global temperature have historically had major effects on the ecological balance, and on the actual geography of the Earth.

Agro forests the miyawaki method and its adaptation to our indigenous conditions for attaining food sufficiency making carbon neutral

1. Miyawaki showed that natural Japanese temperate forest should be mainly composed of deciduous trees – while in practice conifers often dominate. Deciduous trees are still present around tombs and temples, where they have been protected from exploitation for religious and cultural reasons. This is true to our ecological system wherein we protect trees mainly the banyan tree in and around our temples and religious centres which is the largest oxygen source and a good natural mechanism to maintain carbon neutrality. The vast study of kavu related ecology (which is a traditional system of ecological conservation in many parts of Kerala) had proved the eco system was well maintained and the soil water and atmospheric temperatures where in a balanced stage in such human adaptation. So while we adapt this Miyawaki method it can be synchronised with the traditional kavu model.

2. His another rather first observation was that the field trials conducted with planted forests, shown that the composition and structure were closer to what would exist in the absence of human activity and it grew quickly and generally showed very good ecological resilience.

When we adapt this to our system, we will have to understand the traditional conservation methods adopted earlier and how it can be made good for the society and ecology as a whole; this will lead to our old homestead farming methods, where several tree crops mainly fruit crops were planted in each backyard for their home purpose which gave good yield and are less disturbed by the planters, so a more refined method of miyawaki system when adopted in fusion

with the traditional backyard can be a good proportion to address the soil conservation, water use, food security, and ecological balance.

3. Miyawaki had formed a large seed bank; with more than 10 million seeds, identified and classified, according to their geographical origin and soil. They are mostly remnants of natural forests preserved for generations around temples and cemeteries because of the traditional belief in Chinju-no-mori (literally forests where the gods dwell;; it was considered unlucky to interfere with these forests). These places have allowed the preservation of thousands of small reserves of native species and tree genes descending from prehistoric forests. Using these principles of Miyawaki the traditional system for restoring native forests for environmental protection, can be made good and this can be a good water retention resource as well as a protection system for controlling natural hazards like floods; this should be linked to our river conservation projects on an urgent basis since there are around 44 rivers in Kerala and most of them are encroached or being exploited by human intervention which is also one of the major causes of natural calamities. The rivers when affected the impact is huge with backwaters, sea and ocean at large which will have a serious economic and environment impact. So this Miyawaki method implementation in these river banks has to be given impetus for its restoration and its linking to our livelihood programs may lead to economic stability, food security and inclusive growth.

Backyards – A Kerala Perspective

Kerala- the God's own country is a lush green land with full of coconut trees, paddy, spices, rubber, arecanut, beetle vines, tree crops, bamboo, cashewnut, tuber crops, flower crops, mangoes, jackfruit and other fruits and vegetables along with tea and coffee; blessed with unique climate and topography. It is having an area of 38855 sq. kms and a population of 3.5 crores (appx). The state is bestowed with high literacy and is renowned for its health and hygiene. The state's economy is basically agrarian in nature. There are 41 west flowing and 3 east flowing rivers and the annual rainfall 2900 mm, which are considered as the basic source of irrigation for agriculture; so why can't this Miyawaki method be adopted for farmers and labourers' livelihood and for controlling natural calamities like flood and also ensuring food security is what is brought as a proposal based on the discussions with several farmers across the state. Based on the interactions with the farmers across the state here are a few recommendations which can be adopted.



Recommendations for implementation are as follows

1. Agriculture systems where the backyard farming was prominent earlier has to be blended to Miyawaki method for food security, livelihood, soil restoration, ecology balance, water conservation, and controlling natural calamities like floods.
2. To encourage and promote organic farming in the state, especially with school children and youth; this method can be well adapted since the initial work is not repeated apart from caring the growth which is less cost consuming. Support may be given to children and youth by rooting Corporate Social Responsibility funds so that the Govt machineries are taking less involvement in cost aspect.
3. Farmers should be encouraged to adopt proven scientific organic agriculture practices such as IOFS (Integrated Organic Farming Systems) model developed by ICAR-IIFSR (Indian Institute Of Farming Systems Research, Modipuram) which is more or less our old tradition household system of integrated farming including fruit crops, vegetables, cattle, poultry, and fish farming through pond systems which is less cost consuming and when properly added to a value chain system the farmers income can be increased to many folds. It can also ensure food security. This can have Miyawaki method as a component since farmers are not incurring much cost.
4. Farmers enrolment platform has to be created where any farmer willing to adopt these backyard farming methods need to be supported and may be asked to enroll and make a directory through a decentralized model with the help of local self Govt. This method can promote organic farming in a big way and farmers problem of cost recurrence in future can be well addressed.
5. Promotion of organic farm tours to the certified and licensed farms which adopt Miyawaki method will boost morale of the farmer as well as consumers and can boost the tourism sector as well in the post COVID scenario.
6. The awareness among the educated younger generation about food products and the positive effect of them in the economic and environmental sustainability is positively encouraging.
7. The new set of green consumers developing in the urban area need to be tapped through a proper value chain mechanism and the well acclaimed MIYAWAKI forest system has to be blended with traditional household farming for an environment friendly, food secured system. The banks of the 44 rivers can be made such food forest which will ensure several things viz., river rejuvenation, stop encroachment, reduce thinning of river, food security, rural employment, pond



reclamation, sand availability, stop soil erosion, carbon neutral and less maintenance cost. This method can be well used in other such lands under the Govt where it is put barren.

8. Rice oriented agriculture has to be upgraded to farmer oriented agriculture by keeping in mind the ecology of the land and demand of the new generation. We want a healthy young generation to make it sustainable. Investing in wellness oriented agro fruit crops through Miyawaki method can reduce capital expenditure on health care considerably.

9. Can we think of becoming carbon neutral self sufficient agricultural state which is organic in nature. Healthy living is a need of the hour and promoting farming systems which are eco-friendly can be supportive to the overall environment making the human habitat carbon neutral.

10. Greening every house hold garden can literally boost the mood of farmer or plant enthusiast and help the environment safe by controlling the carbon emission under check.

Conclusion

The vision is for a new generation of agricultural systems models and knowledge products that can help accelerate the rate of agricultural innovation and meet the local need for healthy food. Given the stresses now being placed on the air, land, water and genetic resources on which human life depends, these innovations also must help reduce environmental impacts and enhance the resilience of food systems under changing climate conditions. We foresee the use of the new generation models leading to “virtual” and “computational” agricultural research and development that can complement, and substitute to some degree, for conventional on-the-ground methods. So such agro forests high density backyard farm models can definitely be transforming farming for the new age farmers through system innovation being blended with science and tradition Likewise, significantly improved data and models can contribute to development of advanced farm-management systems, and by making better information available about new systems, could accelerate the adoption and efficient use of more productive and more sustainable technologies. As this is a decentralised model and as Kerala had already implemented the decentralisation plan quiet effectively in the past; these models can become efficient by having essential tools for assessing its socio economic and environmental impact.

AQUAMIMICRY: A NOVEL AND SUSTAINABLE APPROACH

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Abstract

With the growth in aquaculture sector increasing use of antibiotics, chemicals and artificial feed can degrade natural environment, cause disease outbreaks and impact the health of farmed aquatic species. Apart from this, cost involvement on feed is tremendous. Therefore, some eco friendly approach needs to be initiated in order to ensure long term sustainable fish and shrimp farming and to reduce cost of feed. Aquamimicry is an environmentally sound culture technique in which natural conditions of farmed aquatic species are replicated, using fermented rice bran and beneficial bacteria to grow plankton communities which serve as a superior and nutritive food source. This method helps in creating a stable and self sustaining environment and lowers the need for external chemical and other inputs.

Keywords : carbon source, probiotics, fermentation, copepods

Introduction

Shrimp industry is a major component contributing to the global seafood production. However, with increasing demand and expanding culture, it has led to deterioration of water quality, indiscriminate use of antibiotics and other chemicals generating huge amount of waste and disease outbreak. In view of such issues, an innovative approach has been initiated in which the natural environmental conditions are imitated, promotes microbial growth and heterotrophic fauna, maintains stability and reduces feeding cost as well. This approach is known as Aquamimicry method which was first started in Thailand 1990s. It is also known copefloc technology. In this method, carbon ingredients like rice bran, wheat bran or soybean serving as

energy source, along with probiotics are used to enhance the growth of heterotrophic communities mainly copepods which serves as a source of proteinaceous feed and simulate beneficial bacteria thus aiding in water quality management.

HOW IT WORKS

In this method rice bran, a carbon source is allowed to ferment by the addition of probiotics which are beneficial bacteria like *Bacillus sp.* Through fermentation bacteria produces hydrolytic enzymes that breaks down complex nutrient molecules into simpler forms, lowers fibre and anti-nutritional factors (ANFs) thus enhancing solubility and digestibility of the carbon source and boosting its bio-availability. This fermented substrate helps in generating blooms of phytoplankton and zooplanktons with copepods being the dominant species which are fed upon by the farmed shrimps. Fermented rice bran provides a highly nutritive feed composition for the growth of shrimps and the added probiotics utilises the nitrogenous metabolites maintaining water quality and the natural microbial population in water. This eliminates the use of excess supplementary feed and dependency on chemicals to maintain water quality.

When a balanced condition of the natural water composition is created, there is less fluctuations in water quality parameters such as dissolved oxygen, pH etc. so the use of antibiotics is not necessary because rice bran which acts as a prebiotic provides nutrition to the zooplanktons as well as beneficial bacteria, the probiotics, to create synbiotics – a natural blend to promote shrimp growth and a healthy pond environment.

PROCEDURE

After preparing the pond for shrimp culture with suitable water quality parameters, apply the fermented rice bran at the rate of 50-100ml per litre pond water. FRB is prepared by mixing husk less rice bran, probiotics (such as *Bacillus subtilis*, *Bacillus amyloliquefaciens*, and *Bacillus valismortis*) and water which is kept to ferment for about 24 hours. Within 7-10 days, copepods when blooms can be observed in the pond, stock the pond at the rate of 12-15 shrimp post larva (PL) at 30-50 sq. metre. The pond bottom should be dragged gently to avoid sediments accumulation and biofilm formation. FRB and probiotics are applied routinely depending on the turbidity level of pond water @ **1-5 ml/litre**. Species like milk fish and cat fishes can be stocked at lower densities which feed upon the excess natural planktons and detritus in the pond. After completion of the culture period and harvesting of shrimps is done, accumulated debris is such as

black soil is removed. FRB and probiotics are then added to prepare the pond for next culture cycle.

Steps to be followed are –

Preparation of the pond :

- Fill up the pond with water up to a depth of about 80-100 cm using a filter bag of 250-300 μ m mesh size.
- Add probiotics to improve pond health.
- Gently drag the pond bottom using chains or ropes for 7 days to mix the probiotics with pond soil properly and prevent the formation of biofilm.
- Apply tea seedcake (20-30ppm) with FRB to kill any undesirable small fish or eggs present from previous culture operations.
- Further application of FRB in the pond routinely to promote copepod growth.

Carbon source fermentation and its application :

- Add rice bran which should be huskless and water at the ratio of 1:5 to 1:10, mix properly and then add probiotics .
- Provide aeration and keep it for 24 hours to ferment.
- If the mixture turns into finely powdered form then apply it to the pond.

Stocking :

- 12-15 shrimp post larva (PL) are stocked in the pond per 30-50 sq. metre.
- Apply FRB at the rate of 1ml/L in extensive culture systems and 2-4ml/L in intensive culture systems.
- Turbidity level of the water should be about 30-40 cm by sacchi disk measurement. If it is more ,then rice bran amount used should be reduced.
- Go for application of probiotics every month.
- Gentle dragging of pond should be done at an interval of around 2 weeks.

1. Sedimentation pond :

- It receives sediments and debris from the shrimp culture pond.
- Stock it with species like milkfish and catfishes that feed upon and utilize the accumulated debris.

- It should be built deeper than the grow-out ponds, 4m deep at the centre and 2m deep at the outer sides.

Biofilter ponds :

- Overflow from sedimentation pond is collected in biofilter ponds.
- Stock these ponds with filter feeding species like tilapia at low densities.
- The filtered water is then redirected to the grow out ponds.

2. Harvesting :

- After harvesting of the shrimps, clean the pond bottom from any remaining debris.
- Then add FRB and probiotics for the next cycle.

COMPARISION WITH BIOFLOC TECHNOLOGY (BFT)

Biofloc Technology and Aquamimicry are quite similar in that both the system depends on formation of heterotrophic organisms such as flocs of beneficial bacteria and blooms of zooplanktons specially copepods respectively. But they also differ in that for the formation of bioflocs, C:N ratio has to be maintained near about 15:1 in BFT whereas such strict C:N ratio is not necessary in aquamimicry i.e. addition of the carbon ingredient is not influenced or dependent on the nitrogen input. In BFT continuous aeration is necessary and due to nitrification there might be lowering of pH and alkalinity for which addition of carbon source is required. Moreover, sediments are removed from the culture ponds to separate sedimentation ponds which can be reused by other species rather than allowing accumulation of large amount of bioflocs. Also, aquamimicry is done in large excavated ponds with high stocking density whereas BFT is carried out in smaller confined tanks with low stocking density.

ADVANTAGES OF AQUAMIMICRY

- Water quality fluctuations is comparatively minimised due to presence of natural microbial communities.
- Reduces feed cost
- Good quality cultured shrimps having better growth rate
- Limited water exchange
- Decreases feed conversion ratio (FCR) due to abundance of zooplanktons
- Reduced occurrence of diseases in cultured species
- Reduced reliance on therapeutants

DISADVANTAGES OF AQUAMIMICRY

- It is difficult to apply in indoor culture conditions.
- Large treatment ponds are being used.

Conclusion

Aquamimicry is sustainable and economically viable technology which integrates both conventional and traditional shrimp farming. It has the capability to improvise and increase growth efficiency, immunity and survivability. By mimicking the natural environmental condition, it reduces reliance on supplementary feed, therapeutants thus producing quality shrimps without toxic residues and lowering production cost and harnessing more profits for the farmers.

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USE OF SURFACTANTS IN AGRICULTURE

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Abstract

Surfactants are used in agriculture to enhance the effectiveness of pesticides, herbicides, and other agrochemicals. They improve the wetting, spreading, and penetration of these chemicals, leading to better coverage on plant surfaces and more efficient uptake. Surfactants improve absorption efficiency by multiple ways. In particular surfactants increase the foliar uptake of herbicides, growth regulators, nutrients and defoliant. Therefore, the choice of the surfactants in an agrochemical formulation is crucial. Surfactants include anionic, nonionic, amphoteric and cationic surfactants. This article describes the role, merit, demerit, precautions and properties of surfactants for agriculture uses.

Keywords Surfactant, anionic, formulation, hormones, pesticide, nutrients and foliar spray.

Introduction

Surfactants are compounds that reduce surface tension, allowing liquids like pesticides and fertilizers to spread more easily and effectively on plant surfaces and in soil. This improves the absorption of nutrients and chemicals by plants and enhances the efficiency of crop protection practices. Surfactants are an effective way to improve uptake of nutrients, growth regulators and herbicides. Plants put up many barriers to the retention, entry and transport of

herbicides. These barriers typically are greater for foliar-applied than for soil-applied herbicides. In addition, environmental conditions and plant factors (age, architecture, leaf morphology and leaf arrangement) may decrease herbicidal activity. Adjuvants are commonly used to improve herbicide performance. Spray solution adjuvants are available for a variety of purposes. Some of the more common uses include: 1. Antifoam or defoaming materials, 2. Compatibility agents to aid mixing herbicides in spray solutions, 3. Buffer solutions to change spray solution pH, 4. Foam markers and dyes, 5. Suspension aids to improve herbicide suspension in spray solutions, 6. Tank cleaners and neutralizers, and 7. Surfactants.

Surfactants are a specialized additive formulated to improve the performance of herbicides in spray solution. They are, by far, the most commonly used adjuvant for post emergence herbicides. Surfactants improve herbicide performance as a result of modifying one or more of the following spray solution characteristics: 1. Mixing, or emulsifying and dispersing oil-soluble and water-soluble molecules; 2. Coverage, or spreading and wetting on leaf surfaces; 3. Spray retention, or sticking on leaf surfaces; and 4. Absorption, or penetrating properties. Surfactants are amphiphilic molecules, meaning they have a hydrophilic (water-attracting) end and a hydrophobic (oil-attracting) end.

Types of Surfactants

- 1. Silicone Surfactants:** These are particularly effective at spreading and penetrating waxy plant surfaces, and are resistant to being washed off by rain.
- 2. Nonionic Surfactants:** These are commonly used as emulsifiers, wetting agents, and dispersing agents in agrochemical formulations.
- 3. Other Surfactants:** Newer surfactants like alkyl polyglycosides, ethoxylate saccharose esters, and dimethylethanolamine based esterquats are also being used in agrochemical formulations.

Mode of action

Herbicide spray solution droplets containing surfactant provide greater leaf surface coverage and a greater potential for herbicide absorption into the plant. The main barrier to herbicide movement into the plant is a waxy layer, called the cuticle that covers the entire plant surface. Its purpose is to prevent water loss. It also inhibits herbicide movement into the plant. Herbicides formulated or applied with surfactants reduce the surface tension of water and allow for more effective movement of the herbicide through the cuticle. The performance of most

surfactants results from three important factors: the herbicide, the weed species and environmental conditions. Herbicide.

Functions of surfactants

A. Enhancing Agrochemical Performance

- 1. Improved Adhesion and Spreading:** Surfactants reduce the surface tension of water, allowing agrochemical sprays to spread more uniformly across plant surfaces, ensuring better coverage.
- 2. Enhanced Penetration:** Surfactants help agrochemicals penetrate waxy plant cuticles and soil, facilitating their absorption by the plant or soil.
- 3. Increased Efficacy:** By improving coverage and penetration, surfactants increase the efficacy of pesticides, herbicides, and fertilizers, allowing for better pest control and nutrient uptake.
- 4. Reduced Drift and Runoff:** Surfactants can also help minimize spray drift and runoff, reducing environmental impact and improving precision of application.

B. Improving Soil Health and Water Management

- 1. Enhanced Water Infiltration:** Surfactants can improve water penetration in hydrophobic soils, promoting better moisture retention and nutrient absorption.
- 2. Soil Conditioners:** Surfactants can act as soil conditioners, improving soil structure and water-holding capacity.
- 3. Nutrient Availability:** By improving nutrient availability in the soil, surfactants contribute to healthier plants and higher yields.

C. Other Agricultural Applications

- 1. Foliar Fertilization:** Surfactants enhance the uptake of nutrients through foliar applications, improving the overall health and growth of crops.
- 2. Seed Treatment:** Surfactants can improve the adhesion of seed coatings, enhancing germination rates and early plant development.
- 3. Anti-transpirants:** In water-scarce conditions, surfactants can reduce water loss from plant surfaces, helping plants withstand drought stress.

Surfactants Used in Agriculture:

- 1. Nonionic Surfactants:** These are the most widely used in chemical crop protection are: Silwet L-77, Tween 80, Agri-Dex, Triton X-100 and Sorbitan derivatives

2. Biosurfactants: These are produced by microorganisms and are becoming increasingly Popular as a more sustainable alternative.

3. Other Examples:

I. Cetylpyridinium chloride (CPC): A cationic surfactant used in some pesticides.

II. Fatty acid esters: Used as emulsifiers or oiling agents in various applications, including agriculture.

III. Lecithin: A naturally occurring surfactant from egg yolk or soybeans.

IV. Oil soaps: Historically used to enhance pesticide performance.

V. Silicone surfactants: Used to improve adhesion and penetration, especially on crops with thick waxy leaves.

Functions of Surfactants in Agriculture:

1. Wetting and Spreading: Reduce the surface tension of water, allowing it to spread more evenly on plant surfaces and penetrate leaves.

II. Penetration: Help agrochemicals penetrate the waxy cuticle of plant leaves, allowing them **to** reach the inner tissues where they can act.

III. Adhesion: Improve the adhesion of agrochemicals to plant surfaces, reducing the risk of runoff or wash-off.

IV. Improved Agrochemical Effectiveness: Enhance the overall effectiveness of herbicides, insecticides, and fungicides by improving their application and absorption.

V. Soil Conditioners: Used to improve water infiltration and distribution in the soil, Promoting better moisture retention and nutrient absorption

Merits of Surfactant Use:

1. Enhanced Pesticide and Fertilizer Uptake: Surfactants help break down surface tension, allowing pesticides and fertilizers to spread evenly and penetrate plant surfaces more effectively.

2. Improved Water Penetration: Surfactants can enhance water infiltration and distribution in the soil, leading to better moisture retention and nutrient absorption.

3. Reduced Water Loss: Surfactants can create a thin film on plant surfaces, minimizing water evaporation and reducing stress during dry periods.

4. Precise Spraying: Surfactants can help control droplet size and deposition, reducing off-target movement and improving the accuracy of pesticide applications.

5. Potential for Biosurfactants: Biosurfactants, produced by microorganisms, offer a more environmentally friendly alternative to synthetic surfactants, with biodegradability and lower toxicity.

Demerits of Surfactant Use:

- 1. Potential Toxicity:** Some surfactants, particularly cationic ones, can be toxic to plants and other organisms.
- 2. Persistence and Environmental Impact:** Synthetic surfactants may not biodegrade easily and can persist in the environment, potentially harming soil and aquatic life.
- 3. High Cost:** While biosurfactants are more environmentally friendly, they can be more expensive to produce and may have lower yields compared to synthetic surfactants.
- 4. Foam Formation:** Some biosurfactants can cause excessive foam formation, which can be a problem in certain applications.
- 5. Difficulty in Obtaining Pure Substances:** Isolating and purifying biosurfactants can be Challenging.

Precautions

The following precautions should be taken during application of surfactants with herbicide, pesticide, growth hormones and nutrients etc

- 1. Personal Protective Equipment (PPE):** Always wear appropriate PPE, including gloves, eye protection, and protective clothing, when handling surfactants.
- 2. Ventilation:** Use surfactants in well-ventilated areas or outdoors. If ventilation is inadequate, wear respiratory protection.
- 3. Contact Avoidance:** Avoid inhaling mists, vapors, or sprays, and contact with eyes, skin, and clothing.
- 4. Safe Handling:** Handle containers with care to prevent spillage and damage.
- 5. Storage:** Store surfactants in a safe and secure location, away from children and pets.
- 6. Spill Management:** If a spill occurs, isolate the area, keep unnecessary personnel out, and ventilate the area.
- 7. Hygiene:** Wash hands thoroughly after handling surfactants, especially before eating, drinking, or smoking.
- 8. Environmental Protection:** Avoid releasing surfactants into the environment, such as drains.



- 9. Read Labels:** Always read and understand all safety precautions on the surfactant label before use.
- 10. Proper Disposal:** Disposal of surfactants should be done in accordance with local regulations.
- 11. Over application:** Avoid over applying surfactants, as this can lead to phytotoxicity (plant damage).
- 12. Compatibility:** Ensure that the surfactant is compatible with the pesticide or fertilizer it is being used with.
- 13. Specific Precautions:** Some surfactants, like silicone adjuvants, can increase the potency of spray mixtures and may lead to plant damage if used at high temperatures or with certain herbicides.

Conclusion

Surfactants in agriculture enhance the effectiveness of agrochemicals and improve water management by reducing surface tension, improving wetting and spreading, and increasing penetration into plant tissues and soil. They act as emulsifiers, prevent drift, and enhance adhesion, making agrochemicals more effective and reducing the need for frequent applications.





TURNING FARM WASTE INTO CARBON WEALTH: THE BIOCHAR REVOLUTION IN AGRICULTURE

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Abstract

Biochar has become rapidly considered as an effective instrument for environmentally friendly farming. Converting farm waste into carbon-rich biochar to mitigate climate change and enhance soil health is a reliable technology. Heating crop residues, leaves, manures, or other organic materials in a low-oxygen atmosphere produces biochar. This process fabricates a soil-friendly product while trapping carbon. Biochar addition in the soil ecosystem uplifts water retention capacity, prevents nutrients from being washed away, encourages beneficial microorganisms, and lower pollution levels. Due to its intrinsic properties, the crop can thrive even in poor or contaminated soils. Biochar reduces the need for chemical fertilizers and helps to cope with climate change by storing carbon reserves in the ground. This article explores how biochar is produced, how it works in the soil, and how it benefits farmers and the environment. On building a greener and more productive future for agriculture, using biochar can turn today's waste into tomorrow's wealth.

Key words: Biochar, Farm waste, soil health, climate change, carbon wealth

Introduction

Farmers worldwide face many issues, including poor soil, highly-priced fertilizer, and the effects of climate change, such as floods and droughts. To sustain these constraints, agriculture is evolving with innovative technologies for crop production. Every farm produces a lot of waste, including manure, leaves, husks, and crop stalks. On handling the organic waste, farmers typically burn or allow it to decompose, both are harmful to the environment. Scientists have

discovered an innovative approach to convert organic waste into biochar, a black substance that looks similar to charcoal and benefits crops and soil. Farm waste is heated in a low-oxygen atmosphere to produce biochar. The residue is changed into a stable carbon form by a process known as pyrolysis. Biochar is a type of charcoal that decomposes more slowly than compost. It can remain buried in soil for centuries, fight climate change by preserving carbon stock, and enhance soil fertility.

Regarding soil, biochar provides the following advantages: improves its physical structure, enhances nutrient use efficiency, and increases water holding capacity. Furthermore, biochar offers an ideal environment for the microorganisms, which promotes soil fertility and crop growth. Biochar encourages plant growth and increases production even in nutritionally deficient, dry, or salty soils. Biochar can restore contaminated soils through its pollutant adsorption potential on its surface. When implemented correctly, it reduces greenhouse gas emissions from agriculture and lessens the need for chemical fertilizers. In short, biochar turns everyday farm waste into a valuable tool for better farming and a healthier planet.

Production techniques of biochar:

Biochar production involves various thermochemical processes that convert biomass into a stable, carbon-rich material. The primary techniques include pyrolysis, gasification, hydrothermal carbonization (HTC), and torrefaction.

Pyrolysis

Pyrolysis is the most common method for producing biochar. It involves heating biomass without oxygen, leading to thermal decomposition. Fig. 1 represents the pyrolysis process for making biochar. Three types of pyrolysis methods exist, which include,

Slow pyrolysis- operates at lower temperatures (300-800°C) with longer residence times, favoring higher biochar yields.

Fast pyrolysis- operates at higher temperatures (450-600°C) with short residence times, primarily producing bio-oil, with less biochar yield.

Flash pyrolysis- operates at extreme temperatures (800-1000°C) with short contact times.

Gasification

Gasification partially oxidizes biomass at high temperatures (750-1000°C), producing syngas and a smaller fraction of biochar. This process is more energy-intensive and yields less biochar compared to pyrolysis.

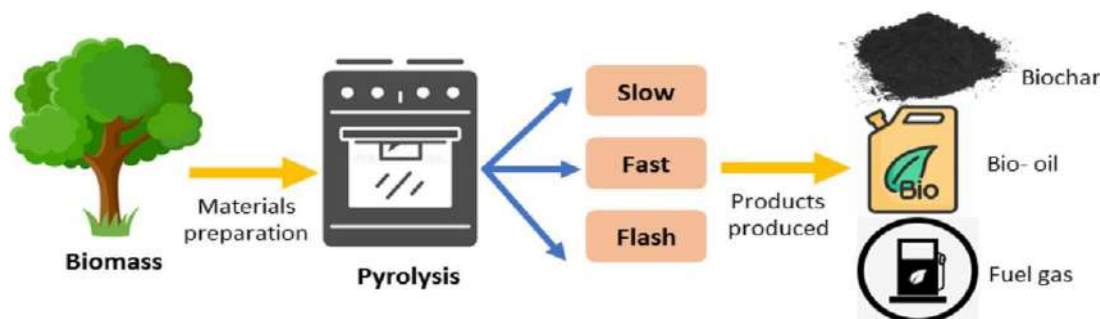


Fig 1. General concept of the pyrolysis process.

Hydrothermal carbonization (HTC)

HTC processes typically biomass with moisture at temperatures of 180-260°C under pressure (10-50 bar). This method is suitable for **high-moisture** feedstocks and produces a product known as hydrochar.

Torrefaction

Torrefaction heats biomass at a range of (200-300°C) in a low oxygen environment, resulting in a product with improved energy density and hydrophobicity. While it produces less biochar, the resulting material is easier to grind and transport. Each method offers clear advantages and is chosen based on factors like feedstock type, desired biochar properties, and planned application.

Physicochemical properties of biochar

Biochar's unique physical and chemical properties vary based on the material used (called feedstock) and how it's made (temperature, time, and method). These properties determine how well biochar works in soil, water retention, nutrient holding, and pollution cleanup.

Porosity and Surface Area

Biochar has a honeycomb-like structure with lots of pores. When farmers heat crop waste to make biochar, the process creates thousands of tiny holes and tunnels inside each piece. These pores are like storage rooms that soak water, air, and nutrients. Biochar has more space to:

- ✓ Hold water and nutrients like a sponge.
- ✓ Provide homes for beneficial microbes.
- ✓ Help roots access moisture during dry spells.

Higher pyrolysis temperatures usually create biochar with more surface area and more pores.

pH (Acidity or Alkalinity)

Most biochar is alkaline (basic), primarily made from manure or high temperatures.

It can raise the pH of acidic soils. Biochar helps neutralize acidic soils, improving nutrient availability and creating a healthier soil environment for plants and microbes. However, some biochar can be acidic, especially that made from wood at low temperatures.

Cation Exchange Capacity (CEC)

CEC measures how well biochar holds onto nutrients (like calcium, magnesium, potassium, and ammonium) and releases them slowly to plants. Biochar improves the soil's capability to retain nutrients and prevent leaching, making it especially useful in sandy or nutrient-poor soils.

Carbon Content and Stability

Biochar contains a high amount of stable carbon, which does not break down easily. This allows biochar to store carbon in the soil for hundreds of years, helping fight climate change. Biochar produced at higher temperatures is more **stable and has** a higher aromatic carbon structure.

Nutrient Composition

Depending on the feedstock, biochar may contain nutrients in its composition, viz., 1) Nitrogen (N) for leaf and stem growth, 2) Phosphorus (P) for strong roots, 3) Potassium (K) for flowering and fruiting and 4) Calcium (Ca) and Magnesium (Mg) for overall plant health

Functional Groups

Biochar surfaces contain functional groups like hydroxyl (-OH), carboxyl (-COOH), and others. These are like little hands that help biochar to do its job in the soil. This dictates the binding potential of pollutants, improves nutrient holding, and influences how biochar interacts with soil particles and microbes. They play a significant role in removing heavy metals and organic toxins from soil or water.

Impact of biochar on soil fertility and crop yield

More than just a soil additive, biochar is a living part of the ecosystem. When mixed into soil, it does much more than hold water or nutrients. It leaves a reaction chain in the root zone, transforming soil, microbes, and plant growth dynamics. Fig. 2 illustrates the benefits of biochar in the soil atmosphere.

Water Holding Capacity

Biochar acts like a sponge in the soil. Its tiny pores, created during heating, store water and slowly release it to plant roots. This makes it especially useful in:

- ✓ Sandy or degraded soils that struggle to retain water
- ✓ Drought-prone areas, where every drop counts

- ✓ Saline soils, where biochar also helps ease salt stress

Studies show that biochar improves pore structure, increases aggregate size, and decreases soil bulk density, leading to better water retention and less erosion.

Carbon Sink in soil

Biochar isn't just suitable for crops, it's good for the climate. When farmers pyrolyze crop waste and add biochar to their soil, they lock carbon into the ground for hundreds of years. Unlike compost or plant residues, which break down and release CO₂, biochar stays stable and prevents carbon from re-entering the atmosphere. This turns farmland into a carbon sink. Even nano-biochar and acid-treated biochar increase soil moisture up to 93%.

Pollutant degradation

Biochar helps to maintain soil health by restoring damaged and polluted land. It adsorbs toxic heavy metals like cadmium, lead, and arsenic, as well as organic pollutants such as pesticides, synthetic dyes, and petroleum compounds. Even nano-biochar has shown promise in cleaning contaminated fields and improving wheat photosynthesis and growth in metal-stressed soils.

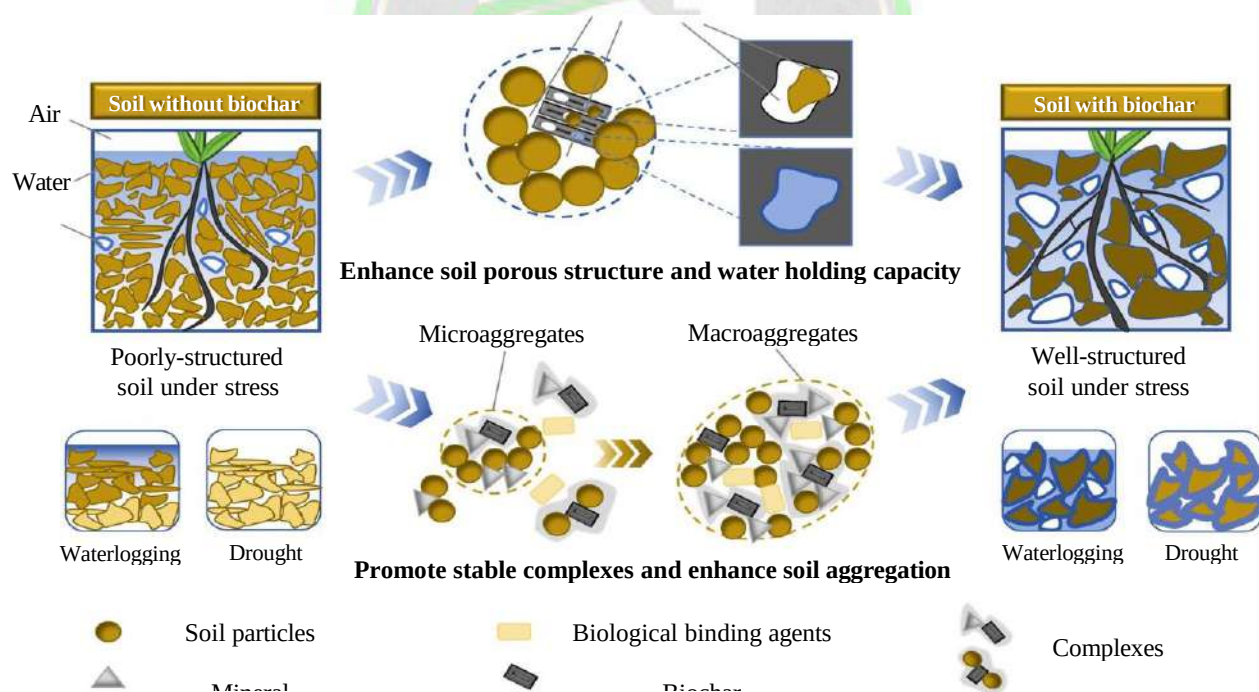


Fig. 2. Effect of biochar on promoting soil structure by improving soil physical properties.

Active mechanisms in the soil and plant system

First, biochar becomes a home for good microbes (tiny living things in the soil).



These microbes live in the small holes in biochar and help plants grow better. One special type, called arbuscular mycorrhizal fungi (AMF), connects to plant roots and helps them absorb more nutrients, like phosphorus. At the same time, biochar helps reduce the harmful microbes that make plants sick. Biochar also holds onto essential nutrients that plants need. It works like a slow-release mechanism, keeping nutrients in the soil and gradually giving them to plants. This prevents nutrients from being washed away by rain and runoff.

In challenging conditions, like dry, salty, or poor soil, biochar helps plants grow stronger. It keeps the soil loose, holds water, and protects roots from harmful elements like heavy metals.

Biochar traps hazardous chemicals and facilitates the breakdown of toxic substances into simple compounds through soil microbes. In simple words, biochar is a natural helper. It improves the soil, feeds the plants, supports microbes, and protects roots. This makes farming easier, cleaner, and better for the future.

Future thrust and conclusion

Biochar has already proven to be a helpful tool for the farming community, improving soil, supporting crop growth, and storing carbon in the soil. But its journey is just beginning. Researchers are investigating methods of producing biochar from various agricultural waste products and using different production techniques. This approach will allow farmers to select a specific biochar best suits their soil composition and crop type needs. Furthermore, there is growing interest in using biochar as a carrier for compost and organic fertilizers.

Biochar has unlimited potential impact, which can be amplified with the help of government policy, agricultural stakeholders, and farming cooperatives through advocacy, resources, workshops, and campaign days. Increased support and education can empower small- and large-scale farmers to utilize farm waste effectively to aid biochar adoption in regions of low soil health or drought.

In summary, biochar is more than just a soil additive. It's a natural solution to many farming challenges, from improving soil fertility and crop yield to reducing pollution and storing carbon. With biochar, we can sustainably improve agriculture cost-efficiently and environmentally. Changing farm waste into biochar is a smart step toward a cleaner, greener future. It helps the soil, the farmer, and the planet all at once. That's the power of the biochar revolution.

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CHALLENGES FOR KIWI CROP IN NON-TRADITIONAL REGIONS

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Introduction

Growing kiwifruit in non-traditional regions presents several challenges due to climatic, soil, and market-related factors. Some of the key challenges include:

1. Climate Constraints

Chilling Requirements: Kiwifruit (*Actinidia* species) require a specific number of chilling hours ($<7^{\circ}\text{C}$) during winter for proper bud break. Warmer regions may not provide sufficient chilling.

Heat Stress: High summer temperatures ($>35^{\circ}\text{C}$) can cause sunburn and reduce fruit quality.

Frost Sensitivity: Young kiwi plants are highly susceptible to late spring frosts, which can damage emerging buds and flowers.

2. Soil and Water Requirements

Soil Suitability: Kiwifruit thrive in well-drained, fertile, and slightly acidic soils (pH 5.5–7). Heavy clay or saline soils can hinder root growth and nutrient uptake.

High Water Demand: Kiwifruit require consistent irrigation, and water scarcity can impact fruit size and yield. Poor water management may lead to root rot.

3. Pollination Issues

Kiwifruit plants are dioecious (separate male and female plants), requiring proper pollination. In non-traditional regions, a lack of natural pollinators (bees) can reduce fruit set, requiring artificial pollination or introducing managed bee colonies.

4. Disease and Pest Pressure

New Pests & Diseases: Non-traditional regions may have different pest pressures, such as

borers, aphids, or fungal infections like *Pseudomonas syringae* (bacterial canker).

Fungal Issues: High humidity can increase fungal diseases like Botrytis and root rot.

5. Infrastructure & Market Challenges

Post-Harvest Handling: Kiwifruit need proper cold storage to extend shelf life, which may not be available in new regions.

Market Competition: Established kiwifruit-producing countries (e.g., New Zealand, Italy, China) dominate international trade, making it difficult for new growers to compete.

Transport & Logistics: Proper handling is needed to maintain fruit quality for distant markets.

6. Variety Adaptation

Some commercial kiwi varieties (e.g., Hayward) may not perform well in new regions, requiring the selection of low-chill or heat-tolerant varieties like Gold kiwifruit (*A. chinensis*) or hardy kiwifruit species.

7. Training & Knowledge Gap

Farmers in non-traditional regions may lack experience in pruning, trellising, and disease management for kiwifruit cultivation.

Conclusion

Despite these challenges, kiwi cultivation in non-traditional regions is possible with adaptive techniques such as:

1. Using suitable varieties (heat-tolerant or low-chill kiwis).
2. Improving irrigation and soil management.
3. Providing frost protection (e.g., wind machines, row covers).
4. Ensuring good pollination practices.

INTEGRATING REMOTE SENSING WITH HYDROLOGICAL MODELS FOR IMPROVED EVAPOTRANSPIRATION ESTIMATION

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Introduction

Evapotranspiration (ET), the process of evaporation from the earth surface and transpiration from plants, is a key element of the hydrological cycle and plays a significant role in various environmental processes (Wang *et al.*, 2025). Accurate ET estimation is essential for efficient water resource management, agricultural planning, and climate modeling. Traditional methods for measuring ET, such as lysimeters and eddy covariance systems, are expensive, labor-intensive, and provide limited spatial coverage (Bian *et al.*, 2024). However, Remote sensing can be used as a cost-effective and practical solution for large-scale ET estimation, providing huge and continuous spatial coverage and the ability to monitor areas where in-situ measurements are difficult or impossible (Sharma *et al.*, 2024).

This article provides a comprehensive review of the application of remote sensing in evapotranspiration estimation, focusing on the advancements and challenges in this field. We will explore the fundamental principles of surface energy balance, delve into different categories ET models based on remote sensing, discuss their advantages and limitations, and highlight recent advancements and future prospects.

2. Surface Energy Balance and Remote Sensing

The surface energy balance (SEB) equation is the cornerstone of most remote sensing-based ET models. It describes the dividing of net radiation (R_n) into sensible heat flux (H), latent heat flux (LE),

ground heat flux (G), and changes in heat storage (ΔH) (Liou *et al.*, 2014). The equation is expressed as:

$$R_n = H + LE + G + \Delta H$$

where:

- R_n is the net radiation, the radiation difference between incoming and outgoing longwave and shortwave radiation. It is influenced by factors like solar radiation (R_s), surface albedo (α), and atmospheric emissivity (ϵ_a) and surface emissivity (ϵ_s).
- H is the sensible heat flux, representing the transfer of heat between the surface and the atmosphere.
- LE is the latent heat flux, represents the energy used to change of water from liquid to vapor during ET. This is the primary focus in ET estimation.
- G is the ground heat flux, represents the heat transfer into or out of the ground.
- ΔH is the change in heat storage within the vegetation canopy and soil, often neglected in calculations.

Remote sensing provides crucial data for estimating the components of the SEB equation. For example, net radiation can be estimated from satellite-derived shortwave and longwave radiation data, while thermal infrared (TIR) sensor's Land surface temperature (LST) is essential for calculating sensible heat flux. Vegetation indices (VIs), like the Normalized Difference Vegetation Index (NDVI) obtained from reflected solar radiation in the optical spectral regions, provide information about vegetation cover and biomass, which are crucial for estimating LE (Derardja *et al.*, 2024).

3. Categories of Remote Sensing-Based ET Models

Remote sensing-based ET models can be broadly classified into two main categories: temperature-based and conductance-based models.

3.1 Temperature-Based Models: These models utilize LST from thermal remote sensing to estimate sensible heat flux (H) and then derive latent heat flux (LE) as a residual of the SEB equation. They are further categorized into:

- **Single-source models:** These models treat the land surface as a single homogeneous entity, simplifying calculations but potentially neglecting the heterogeneity of the actual environment. Examples include the Simplified Surface Energy Balance (SSEB) (Senay *et al.*, 2011), the Surface Energy Balance System (SEBS) (Njuki *et al.*, 2023), Surface Energy Balance Algorithm for Land (SEBAL) (Lee *et al.*, 2016) and the Mapping Evapotranspiration at High

Resolution with Internalized Calibration (METRIC) (Kilic *et al.*, 2016). These models have undergone significant development and refinement over time, with modifications to improve accuracy and address limitations in various environmental conditions.

- **Two-source models:** These models explicitly account for the separate contributions of soil and vegetation to the energy balance, providing a more realistic representation of heterogeneous land surfaces. Examples include the Two-Source Energy Balance Model (TSEB) (Li *et al.*, 2019) and the Disaggregated Atmosphere-Land EXchange Inverse (DisALEXI) (Knipper *et al.*, 2019). These models offer improved accuracy compared to single-source models, especially in heterogeneous landscapes.
- **Contexture-based models:** These models leverage the relationship between LST and VIs across areas with varying vegetation fractions to estimate ET. They often utilize simple geometric frameworks, such as triangles or trapezoids, defined by LST and VI values, to determine the evaporative fraction. These models offer a simplified approach for ET estimation, but their accuracy can be limited compared to more complex models.

3.2 Conductance-Based Models: These models typically employ the Penman-Monteith equation, which requires estimates of canopy conductance to water vapour. It is influenced by factors such as canopy structure and stomatal conductance, which can be estimated using shortwave remote sensing data. These models are generally more complex than temperature-based models but can provide higher accuracy under certain conditions (Derardja *et al.*, 2024).

4. Advantages and Disadvantages of Remote Sensing-Based ET Models

Remote sensing-based ET models offer several advantages:

- **Large-scale coverage:** They can estimate ET over large areas, providing regional or even global estimates.
- **Cost-effectiveness:** They are generally more cost-effective than traditional methods, especially for large-scale applications.
- **Continuous monitoring:** They allow for continuous monitoring of ET dynamics over time.
- **Accessibility of data:** Many remote sensing datasets are freely available, making these models accessible to a wider range of users.

However, there are also limitations:

- **Data requirements:** Some models require extensive input data, including meteorological data and ancillary information.

- **Model complexity:** Some models are complex and require specialized knowledge and software for implementation.
- **Atmospheric effects:** Atmospheric conditions can affect the accuracy of remote sensing data, leading to uncertainties in ET estimates.
- **Spatial resolution:** The spatial resolution of remote sensing data can limit the accuracy of ET estimates at fine scales.
- **Calibration and validation:** Accurate calibration and validation of models are crucial for reliable ET estimates, often requiring ground-based measurements.

5. Recent Advancements and Future Prospects.

Recent advancements in remote sensing technology and modelling techniques have significantly improved the accuracy and applicability of remote sensing-based ET models (Hively *et al.*, 2021). These include:

- **Improved sensor technology:** Higher spatial and temporal resolution sensors, such as Landsat-8 and Sentinel-2, provide more information about land surface properties, leading to more accurate ET estimates. Future missions like Landsat Next and Copernicus Land Surface Temperature Monitoring (LSTM) promise even greater improvements.
- **Advanced algorithms:** Developments in image processing and data assimilation techniques have enhanced the accuracy of retrieving key parameters from remote sensing data, such as LST and VIs.
- **Hybrid models:** Combining different models or incorporating machine learning techniques can improve the accuracy of ET estimation.
- **Data fusion:** Integrating data from multiple sources, such as remote sensing, meteorological data, and ground measurements, can improve the accuracy and reliability of ET estimates.

Future research directions include:

- **Developing more robust and accurate models:** Further research is needed to develop models that can accurately estimate ET under diverse environmental conditions and with limited data availability.
- **Improving model calibration and validation:** More effective calibration and validation techniques are needed to ensure the accuracy and reliability of ET estimates.

- **Integration with other data sources:** Combining remote sensing data with other data sources, such as soil moisture data and hydrological models, can improve the accuracy and understanding of ET processes.
- **Addressing uncertainties:** Quantifying and reducing uncertainties associated with remote sensing-based ET estimates is crucial for reliable applications.

Conclusion

Remote sensing is one of the powerful tool for evapotranspiration estimation at regional and global scales. The development of various models, ranging from simple temperature-based approaches to more complex conductance-based methods, has significantly advanced our ability to monitor and understand ET dynamics. Ongoing advancements in sensor technology, modelling techniques, and data integration strategies promise further improvements in the accuracy and applicability of remote sensing-based ET estimation, contributing to better water resource management, agricultural practices, and climate change research. However, careful consideration of model limitations, data requirements, and uncertainties remains crucial for reliable and meaningful applications.

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NUTRITIONAL PROFILE AND VALUE-ADDED APPLICATIONS OF SILKWORM PUPAE

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Abstract

Silkworm pupae (SWP) are a nutrient-rich byproduct of the silk industry, offering high-quality protein, essential fatty acids, vitamins, and minerals. Species like *Bombyx mori* and *Samia ricini* provide a balanced amino acid profile and oil rich in unsaturated fats. SWP also contain bioactive compounds such as chitin, polyphenols, and tocopherols. Beyond nutrition, they are used in food products like sauces, snacks, and baked goods, and have potential in space food systems. This article explores the nutritional profile and value-added uses of SWP for sustainable food solutions.

Keywords: Silkworm pupae, Nutrition, Sericulture, byproduct

Introduction

Silkworm pupae (SWP), once considered a sericulture byproduct, are now recognized for their exceptional nutritional value. Rich in protein, healthy fats, essential amino acids, vitamins, and minerals, SWP offer a sustainable food source with numerous health benefits. They are widely used in traditional cuisines and modern food industries, and even show potential in space nutrition. This article highlights the nutritional composition and value-added applications of SWP, emphasizing their role in enhancing food security and sustainable diets.

2. NUTRITIONAL ASPECTS OF SILKWORM PUPAE:

Protein, fat, and sugar are the most common components in the rich nutritional profile of SWP, although there are many more nutrients present as well, including vitamins, minerals, and polyphenolic compounds. The following nutrient contents are discussed below:

2.1. Protein content:

With 55.6% dry weight, *Bombyx mori* has a high protein content and is the dry matter that is mostly found in the SWP. The SWP are rich in amino acids which can be used as a dietary supplement in human. Therefore, by taking SWP as a protein in food, the nutrients required daily for the body could be supplemented. With the exception of Eri SWP, all species within the SWP contain a total of eighteen amino acids. Eight of these eighteen amino acids are necessary, making up almost 42 percent of the entire number of amino acids. Furthermore, individuals need ten non-essential amino acids. The pupae contain high amounts of Phe and Pro as compared to the protein content in hen. Thus, it is believed that SWP are an excellent supplier of protein. Table 1 presents a summary of the amino acid content found in several types of SWP protein.

Table 1: There are the amino acid compositions of the different varieties of SWP proteins.

Sl No.	Amino Acid (g/100 g of Protein)	Hen Egg	<i>Samia ricini</i>	<i>Bombyx mori</i>	Mulberry SWP	<i>Antheraea pernyi</i>
1.	Ala	5.03	6.05	3.9	5.5	6.26
2.	Arg	5.70	4.41	4.7	6.8	4.12
3.	Gly	3.02	4.94	3.6	4.6	4.42
4.	Glu	12.13	12.9	9.5	14.9	12.74
5.	His	2.09	2.67	2.7	2.5	2.94
6.	Lys	6.59	6.54	6.1	7.5	4.54
7.	Ile	4.88	4.42	3.4	5.7	7.95
8.	Asp	8.92	9.89	9.1	10.9	6.41
9.	Leu	8.11	6.63	6.2	8.3	3.24
10.	Val	5.42	5.36	4.7	5.6	6.63
11.	Met	2.81	2.31	3.4	4.6	1.47
12.	Cys	1.90	0.53	1.4	1.4	1.5
13.	Phe	4.82	5.24	4.6	5.1	8.10
14.	Pro	3.38	6.46	7.0	4.0	12.22
15.	Ser	6.72	5.25	3.7	4.7	4.64
16.	Trp	1.72	NA	1.5	0.9	4.05
17.	Thr	4.47	4.75	3.9	5.4	4.64
18.	Tyr	3.81	6.4	5.6	5.4	2.06

2.2. Oil content:

After protein, the amount of oil in SWP is significant. Instead of dumping away the SWP, we may utilize SWP as foods as well as for viable production of oil, that will eventually assist to decrease malnutrition while enhancing food security. One hundred grams of dried SWP can yield 25–30 gram of SPO (Silkworm pupal oil) using a variety of extraction techniques. There are four species of silkworms, and the pupae of the Eri species contain the highest oil content (26.2%) of any of them. Of the ten fatty acids present in SPO, oleic acid and α -linolenic acid had the highest amount, with α -linolenic acid accounting for 24.30–45.80% of the total. Apart from Myristic acid, there are other fatty acids such as saturated, monosaturated, and polyunsaturated fatty acids, as well as palmitoleic, palmitic, stearic, linoleic and, oleic acids. Omega-3 fatty acids, which are also included in SWP, are crucial for enhancing human health. In addition to oil, the SWP is rich in unsaturated fatty acids, which have nutritional significance as a source of edible oil. Oil is a major nutrient found in the SWP.

2.3 Mineral content:

Up to 25 distinct mineral kinds are found in SWP. These minerals exist in a variety of forms and are essential for physiochemical processes among other things.

The contents of all 8 minerals found in all three distinct kinds of pupae are listed in Table 2. The table shows that the concentrations of magnesium, calcium, and phosphorus are higher. Pupae differ in terms of the minerals they contain depending on their type as well as the surroundings where they've grown. With the exception of the minerals indicated within the table, it's clearly evident that the amount of sodium-to-potassium proportion in the pupae of silkworms is extremely low. Na: K predicts the prevalence of non-communicable diseases, indicating that eating SWP may lessen the likelihood of non-communicable diseases. Some of the non-communicable diseases include heart disease, stroke, cancer, diabetes, chronic lung disease, hypertension, etc.,. Certain pupae have high selenium contents as well, which may be due to an enrichment in the pupae protein. A significant part of cancer prevention and oxidative stress defense is played by the pupae's high selenium content.

2.4. Other Ingredient present in SWP:

SWP also contains many vitamins apart from the above-mentioned components and is rich in them. Vitamins VA, VB1, VB2, VB3, VB5, VB7, VB9, VB12, VC, and VE 19 are the primary vitamins in SWP. Phospholipids and five tocopherols (α -tocopherol, β -tocopherol, γ -

tocopherol, γ -tocotrienol, and σ -tocopherol) are also found in SWP. It also contains some additional components like polyphenols and flavonoids. Also, there are two types of sugars present in the SWP which can be divided into, chitosan and chitin.

Table 2: Mineral makeup of various SWP species

Sl. no	Minerals (mg/100 g Dry Weight)	<i>Samia ricini</i>	<i>Bombyx mori</i>	<i>Antheraea pernyi</i>
1.	Copper	1.75	0.15	0.73
2.	Phosphorus	584	474	272
3.	Calcium	74.2	158	63
4.	Manganese	2.54	0.71	NA
5.	Zinc	7.24	23	3.57
6.	Iron	24	26	4
7.	Magnesium	178	207	154
8.	Chromium	NA	1.69	9.84

3. VALUE ADDITION OF SILKWORM PUPAE:

The pupal composition can be summarized as follows: Protein is abundant, making up 55-60% of the dry weight, Lipids present at a significant level, constituting 26% and free amino acids comprising a smaller portion, ranging from 5-8%. It was found that 100 gms of dried SWP provides 75% of the protein that is needed by an individual. The vitamins and minerals present in the SWP make it more nutritive and are also found to be better for lactating women who mainly live in the tribal areas. Several key properties of the pupal oil, including its refractive index (1.47 at 30°C), acid value (67.37), saponification value (150.88), iodine value (174.91), and low cholesterol content (0.36%), make it highly desirable for potential applications in the food industry. Pupae, the developmental stage between insect larva and adult, serve as a valuable source of oil used in creating highly nutritious amino acids and flavorful products. SWP boasts a nutritional profile comparable to meat, potentially even surpassing options like soybeans, fish, and beef when considering protein, fat, vitamin, and calorie content. The crunchy chitin that is present in the exoskeleton of SWP is used as a supplementary cereal diet among rural people. Moreover, it is found that pupae have vast use in chocolates, chili sauce, etc industries. SWP are also taken as a delicacy by the Chinese and pectin, a valuable byproduct obtained from pupae,

finds diverse applications as a thickening agent in various industries, including fruit juice, ice-cream, jam, candy, and jelly production. SWP exoskeletons serve a surprising purpose like enhancing the volume of bread loaves made from wheat flour and in Japan, silkworm pupal cakes are recognized and sold for their significant nutritional value. The eri pre pupae and pupae are taken as a delicious fry, pakori, chop, and cakes. Research suggests that pupal protein could be a viable dietary option for crews inhabiting CELIS (Control Ecological Life Support) a cutting-edge, self-contained ecological system known for its complexity. During COSPAR's (Committee on Space Research) 36th Scientific Assembly, JAXA (Japan Aerospace Exploration Agency) unveiled a recipe incorporating pupae as a potential food source for astronauts.

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PESTS OF SILKWORMS

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Introduction

Silkworms, which are the larvae of the silk-producing moth *Bombyx mori*, are susceptible to various pests that can negatively impact their growth and silk production. Here's a detailed overview of some common pests that affect silkworms

1. Uzi fly: *Exorista bombycis* Weidman (Tachinidae: Diptera) syn. *Exorista sorbillans* , *Tricholyga bombycis*

It is a parasitoid of silkworm larvae and pupa, similar to house fly with prominent black and grey stripes, adult lays eggs on the body of the silkworm from third instar onwards, maggot on emergence bores into the body of the silkworm, because of this there is development of black scar or spot on the body of silkworm. The maggot feeds on the tissues, especially the fat bodies, grown up maggot punctures the body of the worm or pupa, comes out and pupates in soil or in cracks of the house, maggots also come out of the cocoon by making the hole and such cocoons become unfit for silk reeling. The extent of damage ranges from 10 – 30 per cent.

Life cycle

Adults are little larger than house fly, blackish grey in colour with four longitudinal black and grey stripes, Female lays eggs on 3rd or 4th instar larvae, A single female can lay about 300-1000 eggs over a period of 9-25 days, Usually 1 or 2 eggs are laid on each silkworm larva, eggs are small, white and are oblong in shape, hatch in 2-5 days after oviposition. Hatched maggots penetrate into the body of the silkworm. Maggots feed on the tissues of silkworm for about a week and fully developed maggot comes out of larva or cocoon killing its host. The maggot which comes out from the body, pupate in the darker area in and around the silkworm rearing

house like corners, crevices, rearing beds, below the ant wells etc. Pupae are light reddish brown to dark reddish brown in colour and are oblong shaped. Adults emerge in about 10-12 days.

Damaging symptoms

Silkworm larvae infested up to early fifth instar die before they reach the spinning stage. If infestation occurs in the late 5th instar, the mature adult uzi fly comes out by piercing the cocoon which renders the cocoon unreelable. Uzi fly infested silkworms or pupae can be identified by the presence of black scar on the part of the skin where the maggot penetrates into the body of the larvae.



Prevention and control of Uzi fly:

1. Rearing rooms should be provided with uzi fly proof wire mesh to doors, windows and ventilators so that adult fly entry into the rearing house can be prevented
2. Making the floor of the rearing house free from cracks and crevices- so that maggots will not get site for pupation.
3. Avoid continuous rearing

4. Physical barrier can be created between silkworm and uzi fly by dusting levigated china clay on the body of silkworm during mounting which prevents the oviposition by the fly. 3-4g/100 spinning larvae or per square ft.
5. Release of Hyperparasitoid of uzi fly, *Nesolynx thymus* (Eulophidae: Hymenoptera) Ectopupal parasitoid. It can be mass multiplied and released in the rearing house which parasitise uzi fly pupa.
6. Spraying of Benzoic acid 1% (commercially available as uzicide, a liquid formulation developed by CSR & TI, Mysore) on silkworm larvae kills the eggs @ 7-8 ml /sq/ft.
 - i. This kills uzi eggs without affecting the silkworm growth.
 - ii. CSR & TI, Berhampore have released Vijeta, a dust formulation having the same properties as uzicide and is easy for operation.
7. Use of uzi trap (developed by CSR & TI) for attracting and killing adults can also reduce the uzi fly damage.

2. Dermestid beetles: *Dermestes ater* DeGeer, *Attagenus fasciatus* Thuberg (Dermestidae: Coleoptera)

The grubs of these beetles feed on the stifled cocoons that are stored for 20-25 days before reeling. They cause severe damage in grainages, particularly on egg laying moths. In reeling house, the adults are attracted to the smell of the dried pupae that comes out from the stifled cocoons and deposit the eggs on the cocoons. The grubs, on hatching bore into the cocoons by making a hole and feeds on the dried pupae. Such cocoons become unfit for silk reeling.



Dermestes ater



Attagenus fasciatus

Management practices

1. Clean the grainage premises and place of storage of cocoons thoroughly, so that continuity of life cycle of the pest is disrupted.

2. Collect the pest insects using a vacuum cleaner, Destroy them by burning.
3. Sun dry pierced cocoons to kill eggs and young grubs and nymphs of pests before storage.
4. Remove pierced cocoons from the grainage premises within four days from the date of completion of grainage operations of a lot and store away from the grainage building.
5. Dispose off pierced cocoons at least once a month.
6. Provide wire mesh to windows to avoid movement of pest insects from the storage of pierced cocoons.
7. Use plastic trays, instead of wooden and bamboo trays in grainages to avoid breeding of insects in crevices inside the grainage.
8. Dust bleaching powder at 200g / sq.ft on the floor near the wall to kill the grubs.
9. Spray stands and room with 0.076% DDVP (Dichlorvos).

3. Ants: *Solenopsis geminata*, *Manomorium phearaonis*, *Camponotus spp.*
(Formicidae : Hymenoptera)

The ants pose a serious problem to silkworms in poorly maintained rearing room, they also attack and fed on the silkworms in rearing trays and also the spinning worms.



Control

Using antwells i.e., providing the legs of the rearing stands with antwells and putting water prevents the climbing of ants to rearing trays.

4. Earwig: *Labia arachidis* Yersin (Labidae; Dermoptera)

They cause severe damage in the grainages, adults usually hide in the trays or in the cracks of the doors, windows and in pierced cocoons (moth emerged). They bite the moths especially the females, kept on the egg card and feeds on the fluid that comes out from the body. Such moths will die before completion of the egg laying.

Control

- Spray 0.028% deltamethrin solution on floor and walls of PC storage rooms.

- Dust 5% malathion on PC, before storing them (5kg dust to cover 50kg PC)
- Dip wooden trays harboring the pests in 0.076% DDVP solution for 2 -3 minutes.
- After 10 days, wash them thoroughly, sundry and use.
- Spray stands and room with 0.076% DDVP solution.

Minor pests of silkworms:

5. Cockroach: *Blatella germanica*, *Periplaneta americana* (Blattidae: Blattoidea)

- Feeds on silkworm eggs throughout the year in grainages.

6. Silverfish: *Lepisma sp.* (Lepismatidae: Thysanura)

- Found in grainages and silk reeling houses and feeds on floss of the cocoon.

7. Psocid: *Liposceis transvalensis* (Psocidae: Psocoptera)

- Commonly found in grainages and cause damage to eggs, seed cocoons and moths.

8. Mite: *Pediculoides ventricosus* (Newport) (Class-Arachnid: Order –Acarina)

- The mites are encountered at the time of re-thatching the roof of silkworm rearing house. They also enter the house along with the building materials such a straw, wood or bamboo. The female usually attacks the silkworms, pupa and adults and feeds.

Control

1. Wheat straw or rice straw should not be kept near the rearing rooms
2. These material can be pretreated with an acaricide like sulphur
3. The rearing appliances should be disinfected with sulphur



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BOTANICAL FEATURES AND ECONOMIC IMPORTANCE OF REDGRAM (*CAJANUS CAJAN*)

Article ID: AG-VO5-I05-104

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Introduction

In India, pigeon pea is split and sold as red gram, which is a popular pulse crop. Arhar and Tur are some of the other names for it. It's a protein-rich food, with about 22% protein content. The latest introductions in red gram often focus on developing drought-resistant varieties, high-yielding hybrids, and varieties with improved disease resistance. It is consumed on a large scale in South Asia and is a major source of protein for the population of the Indian subcontinent. It is the primary accompaniment to rice or roti (flat bread) and has the status of staple food throughout the length and breadth of India. Other than India, red gram is mostly grown and consumed in underdeveloped nations.

Pigeon peas are small, round to oval, mostly cherry-red coloured dicotyledonous seeds in the legume family. They do, however, come in a variety of colour patterns, such as yellow, brown, variegated, and so on. Since its domestication in the Indian subcontinent at least 3,500 years ago, it is now farmed as a significant pulse crop throughout Asia's tropics and subtropics, as well as Sub-Saharan Africa and Latin America, for its nutritious dry seeds. Every Red gram plant is a mini-fertilizer factory as the crop has unique characteristics of restoring and maintaining soil fertility through fixing atmospheric nitrogen in symbiotic association with Rhizobium bacteria present in the root nodules.

Red gram crop is suitable for inter-cropping, with different crops (Cotton, Sorghum, Pearl millet, Green gram, Black gram, Maize, Soybean, Groundnut) for increasing production and maintaining soil fertility. World major redgram producing countries are India (42.80 lakh tonnes), Malawi (4.24 lakh tonnes), Myanmar (3.39 lakh tonnes), Tanzania (1.36 lakh tonnes) and Haiti (1.23 lakh tonnes). advance estimates, all India redgram production in 2022-23 is at 3.89 million tonnes. In India redgram production in 2022-23 is at 1.75 lakh tonnes from 5.55 lakh acres with productivity of 314 Kg/acre, major redgram cultivating states are Karnataka 13.37 lakh ha (33.04 lakh acres), Maharashtra 11.11 lakh ha (27.45 lakh acres), Uttar Pradesh 3.50 lakh ha (8.65 lakh acres), Andhra Pradesh 2.32 lakh ha (5.73 lakh acres), Gujarat 2.27 lakh ha (5.61 lakh acres) and Jharkhand 1.85 lakh ha (4.57 lakh acres).

Advantages of Red gram cultivation

1. Red gram cultivation offers several advantages, primarily due to its nutritional value, soil health benefits its ability to release soil-bound phosphorous and adaptability to various farming conditions. It's a protein-rich staple food, a valuable source of animal feed, and improves soil fertility by fixing atmospheric nitrogen and organic matter to soil.
2. Additionally, red gram is drought-resistant and suitable for dryland farming.
3. Red gram is particularly rich in lysine, riboflavin, thiamine, niacin and iron. In addition to being an important source of human food and animal feed.
4. Red gram can be intercropped with other crops, maximizing land use and diversifying income for farmers.
5. Red gram is an Economically Importance cash crop, providing a significant source of income for small-scale farmers, and it also has export potential.
6. The deep root system of red gram helps to break up hard soil layers, improving soil structure and reducing erosion.

Floral Biology

Red gram (*Cajanus cajan*), also known as pigeonpea, exhibits a floral biology characterized by zygomorphic, bisexual, and complete flowers borne on terminal or auxiliary racemes and are normally yellow in color with some variations. It's an often cross-pollinated crop, but also capable of self-pollination. The flowers typically open in the morning and close in the afternoon, with each flower opening for two or three days. Pollen viability is limited to about two days, and the stigma is receptive for three days. It has ten stamens in diadelphous condition with light or

dark yellow anthers. The ovary is superior with a long style attached to a thickened, incurved, and swollen stigma.

Scientific Name: *Cajanus cajan*

Chromosome Number: $2n=22$

Place of Origin: Africa

Putative Parent: Cultivated *Cajanus* arise from *Atylosia lineata*

Habitat: Tropical

Habit: Annual or Perennial shrub, erect stem and branching type.

Root: Tap root system cluster of root nodules produced under the favorable conditions

Stem: Woody, cylindrical, branching and hairy.

Leaves: Trifoliate compound leaf, central leaf larger, Petiolate, stipulate, palvinate, leaf lamina lancionate and reticulate venation

Inflorescence: Axillary and Terminal raceme.

Flower: Bisexual, complete flower, Papilionaceous, Bracteate, Zygomorphic, Pentamerous.

Calyx: The calyx is campanulate (bell-shaped) with triangular or lanceolate lobes.

Corolla: The corolla has five petals, including a vexillary petal (standard), two wings, and two keel petals.

Androecium: The androecium (male reproductive part) has ten stamens, arranged in a diadelphous fashion (9+1), meaning nine stamens are fused and one is separate.

Gynoecium: The gynoecium (female reproductive part) has a superior ovary.

Color: Flowers are typically yellow, but can have purple or red streaks or be plain red.

Pollination: Red gram is often cross-pollinated, with natural crossing rates ranging from 3-65%.

Anthesis: Flowers open between 8 a.m. and 5 p.m.

Pollen Dehiscence: Anthers start dehiscing (releasing pollen) in closed buds, often a day before the flower opens.

Stigma Receptivity: The stigma is receptive for pollination 68 hours before anthesis and remains receptive for about 20 hours after anthesis.

Fertilization: Fertilization occurs about five hours after pollination.

Flower Longevity: The flowers have a lifespan of a little over two days, typically 47-51 hours.

Seed Development: Seeds are compressed and subspherical, varying in color.

Fruit: The fruit is a linear-oblong, compressed, and bi-valved pod.



Arhar species-North Indian pulse crop

Cajanus cajan var bicolor, perennial and Large bushy plant, bearing purple streaked yellow flower, pod dark purple

Tur species- South Indian pulse

Cajanus cajan var flavus, short duration, colour of standard petal yellow, pod green colour and glabrous.





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ONCE FARMER LABOURERS AND NOW MASTER TRAINER THROUGH SKILL GENERATION

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Introduction

The mood is festive across India as it is the festival of Raksha Bandhan when sisters tie a rakhi thread on their brothers' wrist, praying for their long and healthy life, and receive a token of love. KVK dediapada organized a training programme in collaboration with EDI ,Ahmedabad and trained 20 farm women for making rakhi and jewellery. These women use locally sourced bamboo to make the rakhis, which are eco-friendly but have modern designs. Vasanta ben a tribal farmer of gopaliya village. she is actively involved with KVK also running their SHG and working as a village coordinator in mission manglam programme. She has very keen interest to learn new things.

Sources of motivation:

KVK dediapada home scientist organized 5 days vocational training programme , during this festive season Raksha Bandhan . 20 tribal women from dediapada villages benefited from this initiative. Every woman managed to earn between Rs 6,000 and Rs 10,000 a month by making these eco-friendly rakhis. Each woman was given a target of making at least 20 rakhis a day. Under the guidance of KVK Vasanta ben Kunwar ji attended Eco friendly rakhi making training (5 Days) .during the training programmes she learnt many designs of bamboo rakhi. They were given training to make rakhis out of raw bamboo. KVK trained these women to help them earn a livelihood.



Technology and innovation adoption :

Vasanta ben was very curious to increase her family income through any home based enterprise .she moved up in this direction by attending a training rakhi making leaving her hesitation ,she strengthened her knowledge regarding bamboo rakhi making .Even during training programme she started preparation of various new designs what she learnt in the training. people appreciated her work and their products. every morning, finishing all the household chores, tribal women would set out of their homes and spend the day making bright colourful rakhis.

Results:

After completion of training programme, she met EDI Ahmedabad gave her chance to expose herself as a trainer to trained another group for making rakhi with different material like wool, bamboo and thread. she trained 15 women under her guidance. According to her, this training helps tribal women to make rakhis is also an opportunity to break the stereotype labour work We want to show the country the beauty of our tribal artisans. We enjoy working in groups and creating new designs. And it feels good to earn an additional income. **She earned as a trainer 1000/ per day. total she received 10,000 for 10 days.** she is very happy with this business also she sale their rakhi at village level and local market too.

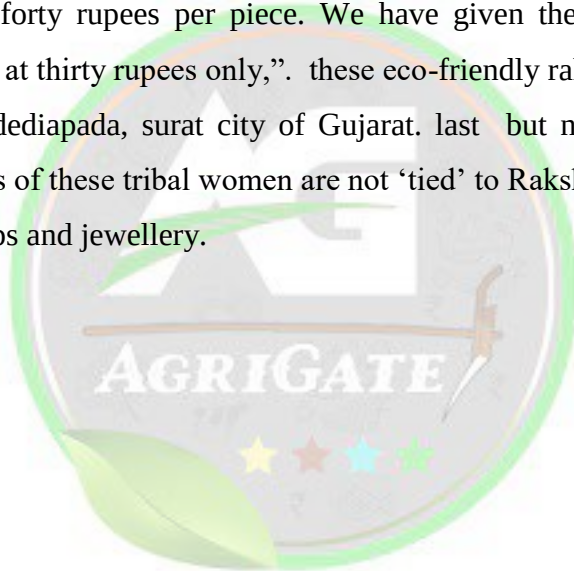
As a Trainer:





Impact :

“Earlier, these women used to do farming and toil in the fields and do labour jobs. Now, they sit under shade, and do the work they like to enjoy,” with their farming. The 30- 40-year-old women are busy in rakhi making that. “It is not easy work. Women have to separate fine threads from raw bamboo. It requires patience and a lot of fine work to make designs. After wrapping threads around bamboo, these are given modern designs, painted, dried, and knot stones. “KVK stressing on increasing the production level. These tribal women are good at production level, but it is difficult for them to sell the products. We aim to provide a marketing ecosystem to our farm women. Vasanta ben said to KVK “Sales are good. People are asking us if our stall will be there before one month of rakhi. Customers are bored of buying rakhis made of stones and pearls, which cost over forty rupees per piece. We have given them a new variety and our bamboo rakhis are priced at thirty rupees only,”. these eco-friendly rakhis are being sold at stalls in the local market in dediapada, surat city of Gujarat. last but not the least word by our entrepreneurs- The efforts of these tribal women are not ‘tied’ to Raksha Bandhan alone. Next on their plan is bamboo lamps and jewellery.





SUSTAINABLE AQUAPONICS FARMING TO BOOST BLUE ECONOMY

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Abstract

Aquaponics is a pioneering model of sustainable farming that marries aquaculture and hydroponics into a synergistic closed system. It establishes a symbiotic association between fish and plants that gain from each other's biological cycles, providing a highly effective solution to the problems of contemporary food production. Fundamentally, aquaponics uses fish waste as a natural plant fertilizer, and the plants filter and clean the water for the fish, producing a balanced, closed-loop system that needs little external input. Aquaponics has several strong benefits that respond to pressing concerns in today's world. Its most significant advantage is exceptional water efficiency, utilizing just 2-10% of the water needed by traditional soil-based agriculture. This conservation is made possible by constant recirculation and reuse of water in the system. The technology allows for simultaneous production of protein (fish) and vegetables, achieving highest possible output per unit area with no use of synthetic fertilizers and pesticides. Aquaponic plants generally grow 30-50% more rapidly than those in soil due to ideal nutrient supply and root zone conditions. The controlled system enables year-round production irrespective of outside weather conditions, and the modular nature of the system enables it to be suitable for varied environments ranging from urban rooftops to rural villages. Considerations in implementation are the initial capital, technical expertise demands, and thorough system management. Nevertheless, the long-term advantages of decreased operating costs, steady returns, and high-quality product value generally balance these up-front challenges. With the increase in world populations and

increasing pressure on the environment, aquaponics stands out as a sustainable, scalable means to greatly augment food security with minimal loss of critical natural resources. Its flexibility to operate on different scales - from small family farms to massive commercial ventures –makes it a universally useful instrument in the shift toward a more sustainable farming system globally.

Keywords: Aquaponics, sustainable agriculture, hydroponics, aquaculture, urban farming, water efficiency, organic farming.

Introduction

Aquaponics is an integrated fish and plant production technology, essentially comprising of two sub-systems, viz., ‘Aquaculture’ and ‘Hydroponics’. The underlying principle is to efficiently utilize water to produce two crops rather than one and to partition and share nutrient resources between fish and plants. This farming system is commonly used in resource limited and urban areas to raise both fish and vegetable in an integrated system. Aquaponics involves culture of horticulture plants along with fishes. Many plants are suitable for aquaponics systems, though which ones work for a specific system depends on the maturity and stocking density of the fish. Green leafy vegetables with low to medium nutrient requirements are well adapted to aquaponics systems, including capsicum, tomatoes, lettuce, cabbage, lettuce, basil, spinach, chives, herbs, and watercress.

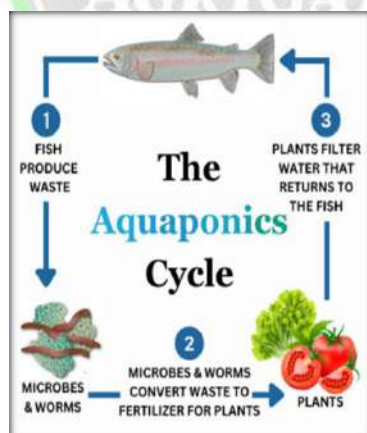


Fig. 1 Aquaponics cycle

Resources

Aquaponics is often hailed as the future of food production. Aquaponics Systems are said to utilize only 2 to 10% of the water required in traditional vegetable or crop production and have the potential to produce 10 times the output, without the use of harmful chemicals, pesticides, etc. The most significant aspect of Aquaponics is the minimum extent of land/ space required,

leading to what is being dubbed as Urban Aquaponics/ Urban Agriculture/ Urban Farming/ Urban Gardening/ Terrace Gardening/ Vertical Gardening/ Office Farm (indoor), etc. Being highly efficient, utilization of natural resources is very limited and results in conservation of precious natural resources like water, land and environment.



Fig. 2 Complete Aquaponics setup

Types of Aquaponics Systems

1. Media-Based Aquaponics

- Plants grow in inert media (gravel, clay pebbles, or perlite).
- Best for: Root vegetables, herbs, and fruiting plants.
- Advantages: Simple, low maintenance, and excellent biofiltration.

2. Nutrient Film Technique (NFT) Aquaponics

- A thin film of water flows through PVC channels where plant roots absorb nutrients.
- Best for: Leafy greens (lettuce, basil, spinach).
- Advantages: Efficient water use, scalable for commercial setups.

3. Deep Water Culture (DWC) or Raft System

- Plants float on polystyrene rafts with roots submerged in water.
- Best for: Fast-growing greens and herbs.
- Advantages: High yield, minimal clogging, ideal for large-scale production.

4. Vertical Aquaponics

- Stacked layers maximize space, often used in urban farming.

- Best for: Small spaces, indoor farming, and high-density crops.
- Advantages: Space-saving, high productivity per square foot.

5. Hybrid Systems (Combining Methods)

- Integrates media beds, NFT, and DWC for flexibility.
- Best for: Diversified crops and optimized nutrient flow

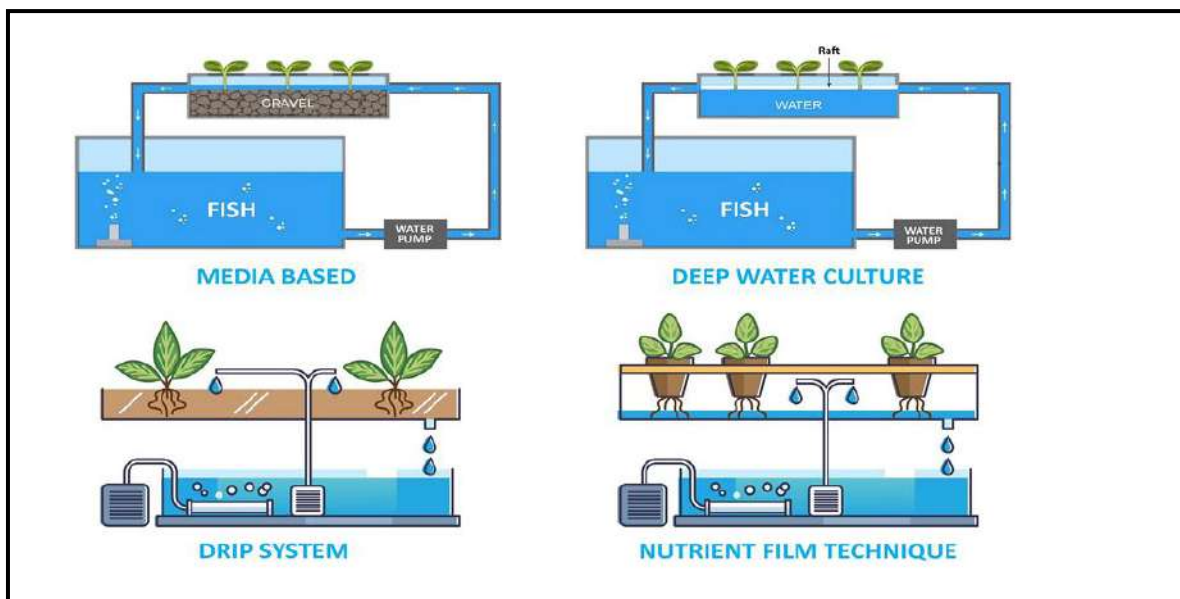


Fig. 3 Types of Aquaponics system

Status and Potential

Our country is leading in freshwater fish production as farmers have achieved impressive yields even in traditional methods of fish farming by harvesting anywhere between 2–10 tonne per hectare per year. However, an Aquaponics System can produce upto five times the quantity of fish in same area per year, besides a good crop of vegetables. Aquaponics is relatively a new practice in our country. Establishment of these units will there for improve the knowledge base of fish farmers about emerging and future technologies in aquaculture.

Operation of these units is more demanding in terms of technology, techniques, biology of cultured fish and stringent water quality parameters. In view of the shrinking resources of land and water, growing population, urbanization and change in life-style, there is a great demand for fresh, hygienically and organically produced fish and vegetables in the cities. Therefore, Aquaponics has a huge potential for integrated fish and plant production in urban as well as rural settings.

Project Location and Implementation

A. Site Selection: Selection of a good site is extremely important, although Aquaponic Systems are suitable where only limited water is available for removal of fish wastes out of the production system. Passing water through a treatment unit removes ammonia and other waste products achieving the same effect as a flow-through configuration. Land/ space measuring at least 150 m² for a Backyard-type Aquaponics unit and 2000 m² for a Small- scale Commercial Aquaponics unit are required for the construction.

B. Beneficiaries: Beneficiaries include women SHGs/ fisherman societies/ fish farmers/ entrepreneurs; selection would be based on their interest and awareness. Beneficiary selection is done through a notification and NFDB Website.

C. Project Implementation:

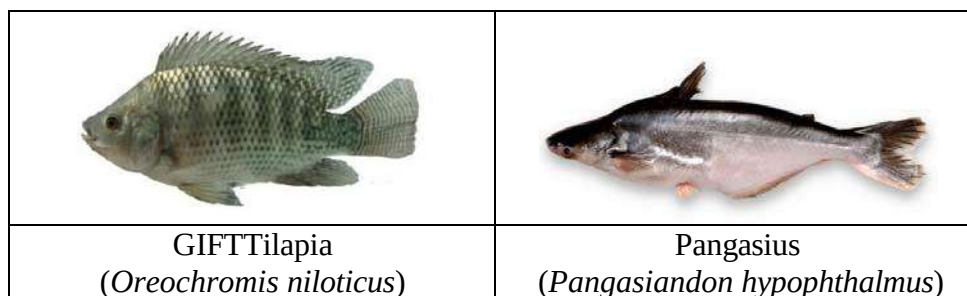
- Project will be implemented by the beneficiary with technical support from the Designated Technology/ Service Provider and Dept. of Fisheries of the State Govt.
- Financial assistance in the form of subsidy will be obtained from Govt. (Central/State) and the remaining amount will have to be borne by the beneficiary through self-finance, bank loan, etc.

Project Components

I. Water Quality: Water quality is important and optimum range of certain parameters required for successful fish culture in an Aquaponics System are as follows:

Sl. No.	Water Parameter	Optimum Range
1	Temperature	26 -30 °C
2	Dissolved Oxygen	4 -6 ppm
3	pH	7 -8
4	Alkalinity	120 -150 ppm
5	Ammonia	<0.05ppm
6	Nitrite	<0.5ppm
7	Nitrate	<5ppm

II. Targeted Fish Species: Monosex Tilapia (*Oreochromis niloticus*), Pangasius (*Pangasiandon hypophthalmus*) or any species that can tolerate high density stocking are suitable for Aquaponic System.



D. Model Unit: Particulars of the ‘Small-scale Aquaponics Unit’ designed by M/s Spacos Innovations, Chitradurga, Karnataka are given here as an example:

(i) Fish Pond/Tank: Area required for construction of the fish pond/tank is 80 m²; diameter of the circular tank is 7.2m, having a volume of 60m³(60,000litre), with effective water depth of 1.68 m and maximum depth of 2.13m (centre of the pond/tank). The system is designed to handle more than 50 fish/ m³(total 3000 fish). Details of design of pond/ tank are as follows:

Sl. No.	Particulars	Unit
1	Total L and Area required	Maximum of 150 m ²
2	Tank Area	80 m ²
3	Circular Tank Diameter	7.2 m
4	Tank Volume	60m ³ (60,000 litre)
5	Effective Depth	1.68 m
6	Maximum Depth	2.13m (centre of the pond)

(ii) **Plant Grow-Beds:** Number of grow-beds in FRP Tanks 10, dimension of each grow-bed 6 x 2 x 1 ft (1.83 x 0.61 x 0.30 m); different kinds of solid media such as gravel or expanded clay pebbles (hydrotons) or lightweight expanded clay aggregate (LECA) are used to grow plants, through which water from fish tank passes. Design and layout of the fish tank and grow-beds is shown below:

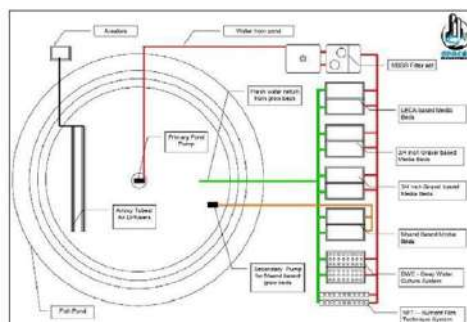


Fig. 4 Lay out of Small-scale Aquaponics Unit

- (iii) **Moving Bed Biofilm Reactor & Filtration:** One Moving Bed Biofilm Reactor (MBBR) and Filtration Unit is installed for water treatment in the Aquaponic System.



- (iv) **Stocking and Yield:** Although stocking densities should be determined by species requirements and operational considerations, the influence of stocking densities on growth and production has been determined empirically. The indicative stocking and harvest details of fish and plants are as follows:

Sl. No.	Component	Salient Feature
I	Fish Culture	
1	Fish Tank volume	60 m ³
2	Moving Bed Biofilm Reactor& Filtration Unit	One Set
3	Targeted Species	GIFT Tilapia (<i>Oreochromis niloticus</i>) and Pangasius (<i>Pangasiandon hypophthalmus</i>)
4	Fingerling stocking (50/m ³)	3000 nos.
5	Fish Culture period	5-6months
6	Survival	90% (2700 nos.)
7	Average body weight	750 g
8	Expected Yield/unit/cycle	2700fish x 750 gm = 2025 kg
9	Total Production/unit/year	2025kg x 2 cycles =4050 kg per year

II	Vegetable Cultivation	
1	No. of Plant Grow-beds	10 nos.
2	Plant varieties	Tomato, Mint, Chilly, Lettuce, Basil
3	Planting density	15– 20 saplings / bed
4	Total no. of Plant	150-200plants
5	Plant cultivation period	Throughout the year
6	Harvest type	Partial harvest
7	Expected yield /bed/year	5-10kg/ bed/ year

1. Commercial Aquaponics Unit

An extent of 0.5acre (2000 sq m) land would be ideal for establishing a Small-scale Aquaponics Unit to be run on commercial lines. It would essentially comprise of one Rectangular fish tank, 10 grow-beds for plants, besides Moving Bed Biofilm Reactor (MBBR) and Filtration Units, Pumps, Aerators, etc. The approximate capital cost would be about Rs. 3.7 lakh and operational costs Rs.4.1 lakh (total Rs.7.8lakh).

The technical details, design and layout, probable project cost, and estimated project costs and returns are given below:

A. Technical Details (Indicative)

Particulars	Details
Fish Culture Tank	
Tank Size & Volume	12 x 5 x 2 m (120 m ³)
Effective Water Volume	100 m ³
Vegetable Growing Beds	
Individual bed size & volume	6x 2 x 1ft (12 ft ³) (340L)
Depth of the bed	0.3 m
Volume of LECA/bed (2nos.)	150 L/ bed
Quantity of gravel/bed (4 nos.)	150 kg/bed
Quantity of sand/bed(2nos.)	150 kg/bed
Volume of water/bed(2nos.)	500 L/bed
Water Filters, Pumps, Aerators, etc.	

Moving Bed Biofilm Reactor& Filter Set	Two Units
Pumps required (2nos.)	15/18000 LPH
Water flow rate	30/36000 LPH
Aerator(3nos.)	120 LPM
Auto Timer (1no.)	20 min.
Fish Species	Tilapia/ Pangasius/ Koi Carps, etc.
Source of Fish	Registered Fish Hatchery/ Seed Farm
Stocking size	Fingerlings(minimum5g)
Stocking density	50-60/m ³ (5000-6000nos.)
Fish Culture period	6 months
Composition of fish feed	28%protein
Type of fish feed	Pelleted feed
Expected weight gain per fish in6 months	Avg. 500 g
Expected Survival	90%(4500 – 5400 nos.)
Expected Yield/yr	5400 kg/yr
Plant Varieties	Tomato, Mint, Chilly, Lettuce, Basil, Capsicum
Planting Density	15– 20 saplings/ bed
Total no. of Plant	150-200plants
Plant Cultivation period	12 months
Harvest type	Partial Harvest

A. Design and Layout (Representative)

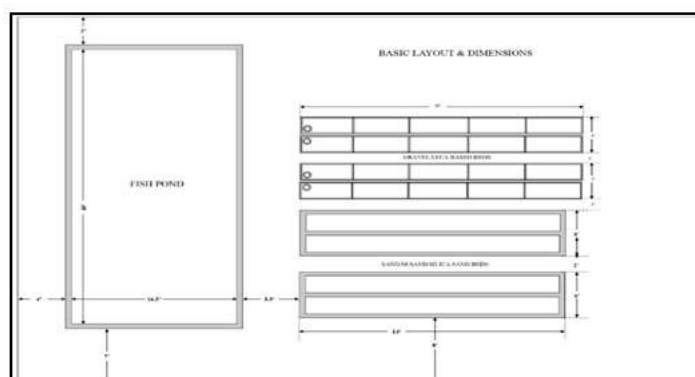


Fig. 5 Layout of the structure



Fig. 6 Picture of the structure



Fig. 7 Picture of the setup

C.Probable Unit Costs

Sl. No.	Particulars	Unit Price (Rs.)	Qty.	Total Cost (Rs.)
A	Capital Cost			
1	Fish Tank Construction (12 x 5x 2 m)	1,00,000	1	1,00,000
2	MBBR& Filtration Units	50000	1	50,000
3	Grow-beds for vegetables	70000	1	70,000
4	Coarsesand& ³ / ₄ " gravel for grow-beds	12000	1	12,000
5	Fish Tank Pump15000 LPH	9000	1	9,000
6	Air-oxytube (m)	200	10	2,000
7	Aerators (for Oxygen supply) 120LPM	10000	3	30000
8	2KVA solar inverter for power backup	40000	1	40,000
9	Bio security fencing for fish tank	20000	1	20,000
10	Plumbing items	30000	1	30,000
	Sub-Total A			3,63,000

B	Operational Cost			
1	Tilapia seed(annually2cycles)	5	12000	60,000
2	Feed cost(annually2cycles)	35	8500	2,97,500
3	Horticulture sapling	3	1000	3,000
4	Electricity cost (units consumed x cost per unit) per annum (2 cycles)	10	5400	54,000
	Sub-Total B			4,14,500
C	Total (A+B)			7,77,500

D. Estimated Project Costs & Returns

Sl. No.	Particulars	Amount/Quantity
1	Culture period for fish(months)	6monthseach crop, total 2 crops
2	Fish fingerlings stocked (nos.)	6,000 nos.
3	Expected Survival	90%
4	Total Fish survived(nos.)	5400 nos.
5	Average harvest size (g)	750 g
6	Expected Production (kg/crop)	5400 nos. x 750 =4050 kg
7	Total Production per year(2crops)	4050 kg x 2 =8100 kg
8	Sale price of fresh/live fish (Rs/kg)	Rs. 150
9	Gross Income Per Year (Rs)	
	From Fish (8100kgx Rs.150)	12,15,000
	From Vegetables (Rs.)	73,300
	Total Income(D)(Rs.)	12,88,300
10	Net Profit/Year(D-C) (Rs.)	5,10,800

3. Economic viability:

Aquaponics offers a diverse and stable polyculture system that allows farmers to grow vegetables and raise fish at the same time. By having two sources of profit, farmers can continue to earn money even if the market for either fish or plants goes through a low cycle. The flexibility of an aquaponic system allows it to grow a large variety of crops including ordinary vegetables, herbs, flowers and aquatic plants to cater to a broad spectrum of consumers. Herbs, lettuce and specially greens such as basil or spinach are especially well suited for aquaponic systems due to their low nutritional needs. For the growing number of environmentally conscious consumers, products from aquaponic systems are organic and pesticide free, whilst also leaving a small environmental footprint. Aquaponic systems additionally are economically efficient due to low water usage, effective nutrient cycling and needing little land to operate. Because soil isn't needed and only a little bit of water is required, aquaponic systems can be set up in areas that have traditionally poor soil quality or contaminated water. More importantly, aquaponic systems

are usually free of weeds, pests and diseases that would affect soil, which allows them to consistently and quickly produce high quality crops to sell.

There are two primary aquaponic systems: Single Recirculating Aquaponic Systems (SRAPS or coupled systems) and Double Recirculating Aquaponic Systems (DRAPS or decoupled systems). The primary difference is that in a DRAPS system, the water from the aquaculture (fish) system is used to provide nutrients to the hydroponic (plant) system but the two systems operate autonomously of each other. Unlike with SRAPS, a grower can add synthetic fertilizer into a DRAPS system without hurting the fish. DRAPS tomato systems that use fertilizers in addition to fish waste can provide the same level of production as conventional hydroponic systems while reducing fertilizer usage by 23.6%. SRAPS systems are not able to mimic these results. Additional research shows the support that aquaponic systems can use 14% less fertilizer than hydroponic systems. Despite this reduction, a grower should determine if the cost of maintaining aquaculture is cheaper than the use of extra fertilizer in hydroponics.

Other non-system-based barriers to the economic success of aquaponic systems could include that these systems require a high degree of knowledge in multiple disciplines, a lack of financing opportunities for aquaponics, and the fact that the general public doesn't understand what aquaponics is. An aquaponics business may require additional branding strategies compared to hydroponics, which is a technology that is relatively well known at this point in the United States.

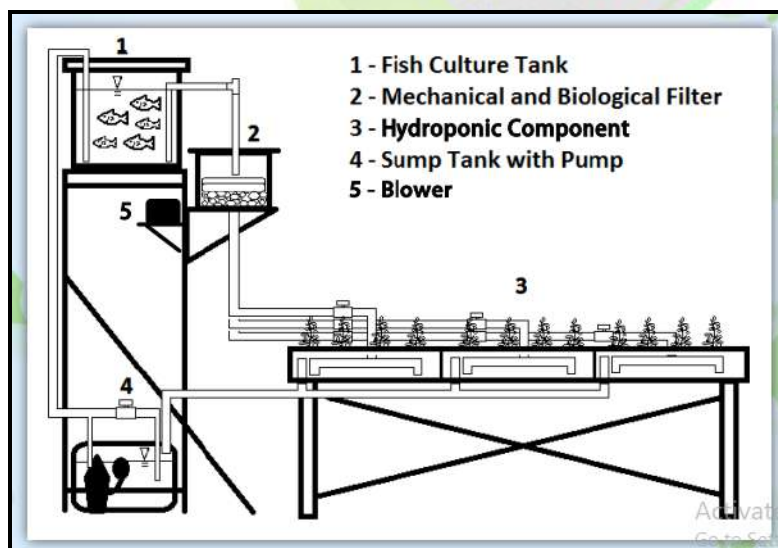


Fig. 8 Flow diagram

With an impressive fish culture potential in the Sundarbans, it is imperative to incorporate mangrove friendly aquaponics related systems in the region. This can improve the alternate sources of livelihood for the people of the Sundarbans, along with increase in mangrove cover with proper management of water. A comparison on the annual seaweed yield from various parts of the Indian coastline, Gujarat tops the list with production figures of nearly over 100,000 tonnes and next in line is Tamil Nadu, about 60,000 tonnes. West Bengal has no production data available, in spite of the coastal aquaculture potential. It is established that aquaponics technology can be effectively used to provide locally grown food for our communities. Ecological technologies with integrated aquaculture can herald a welcome change in the mangrove belt, and with the demand for a steady food guarantee being continuously on high tide, we should rise together to build a sustainable future for our wetlands.

Conclusion

Aquaponics presents a groundbreaking opportunity for small-scale farmers and those with limited land holdings, offering a sustainable and economically viable solution to many challenges faced in traditional agriculture. By integrating fish and plant production in a closed-loop system, aquaponics maximizes resource efficiency, making it particularly beneficial for farmers operating on small plots of land or in urban and peri-urban areas. For small-scale farmers, aquaponics reduces dependency on large tracts of fertile soil, as the system can be set up on marginal or non-arable land, including rooftops, terraces, and backyards. This is especially transformative in regions where land scarcity or soil degradation limits agricultural productivity. The system's water efficiency—using up to 90% less water than conventional farming—addresses critical issues in drought-prone areas, ensuring consistent production even under water-stressed conditions.

Economically, aquaponics diversifies income streams by enabling farmers to harvest both fish and high-value crops like leafy greens, herbs, and vegetables year-round. The premium market demand for organic, pesticide-free produce further enhances profitability. Small-scale farmers can start with low-cost, modular systems and gradually scale up, minimizing financial risk while achieving higher yields per square meter compared to traditional methods. Additionally, aquaponics empowers farmers with greater control over production, reducing vulnerability to climate fluctuations, pests, and market volatility. By adopting this technology, smallholders can transition from subsistence farming to commercial ventures, improving food



security and livelihoods in their communities. In conclusion, aquaponics is not just an innovative farming technique but a catalyst for rural and urban agricultural transformation. For small-scale farmers and those with limited land, it offers a pathway to resilience, sustainability, and economic growth, paving the way for a more secure and prosperous future in agriculture.

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AZOLLA: NUTRITIVE FEED FOR ANIMALS

Article ID: AG-VO5-I05-107**D.K.Bagri¹, R. Kumari² and D.L.Bagdi^{3*}**

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Abstract

Azolla is a good source of high-quality protein, essential amino acids, vitamins- vitamin A, vitamin B12, Beta Carotene, growth promoter intermediaries and minerals like calcium, phosphorous, potassium, ferrous, copper, magnesium etc. Azolla, on a dry weight basis, is constituted of 21-23% protein content, 10-15% mineral content and 7-10%, a combination of amino acids, bio-active substances and biopolymers. Carbohydrate and oil content in Azolla is very low. Thus the biocomposition of Azolla, makes it one of the most economic and efficient feed substitutes for animals. Moreover, Azolla can be easily digested by livestock, owing to its high protein and low lignin content. Azolla can also be fed to sheep, goat, pig and rabbit as feed substitute.

Keywords: Azolla, Animal, Protein, Carbohydrate, Vitamins, Minerals, Protein.

Introduction

Azolla also known as duckweed, mosquito fern or water fern is an aquatic plant that grow rapidly double their volumes in just two days belonging to Salviniaceae family. It grows in fresh water and is naturally available mostly on moist soils, ditches, marshy ponds and is widely distributed in the tropical belts of India. It is considered to be the most promising because of the

ease of cultivation, minimal water for propagation, high productivity and good nutritive value. It was used as feed to juvenile black tiger shrimp, goats and buffalo calves. Whereas *Azolla filiculoides* was also used in diets for sows and as partial replacement of protein source for growing fattening pigs. *Azolla pinnata* was also tried as a protein supplements for Rabbits. It is also a potential source of nitrogen and is a potential feed ingredient for livestock, goatry and backyard poultry. There is an acute shortage of feed and fodder for dairy animals due to climate change and other factors. During present investigations *Azolla pinnata* has been observed as an alternative to green fodder and as supplementary protein diet due to its high palatability and enhanced yield under rain fed condition in lean period. Azolla is a free floating fresh water fern belonging to the family Azollaceae and order Pteridophyta. Azolla is a potential feed ingredient for broilers. Azolla is rich in protein; total protein is 25-30%. Azolla can be used as a plant protein source and provitamins for poultry nutrition (Lejeune et al., 1999). It is also a potential source of nitrogen and is a potential feed ingredient for livestock (Lumpkin, 1984). Azolla can increase flexibility of diet and makes possibility for cheaper production in poultry breeding and have been known as the cheapest and most abundant potential protein sources, because they are able to synthesize amino acids and a wide range of available and unlimited raw materials (Alalade and Iyayi, 2006).

Classification /Taxonomy of Azolla

1. Kingdom: Plantae, 2.Division: Pteridophyta, 3.Class: Polypodiopsida, 4.Order: Polvinales, 5.Family: Salviniaceae 6.Genus: Azolla.

Characteristics of Azolla

Azolla develops a symbiotic relationship with blue green algae, *Anabaena azollae*. An azolla plant is a fern frond consisting of a main stem growing at the surface of the water, with alternate leaves and adventitious roots at regular intervals along the stem. Secondary stems develop at the axil of certain leaves. Azolla fronds are triangular or polygonal and float on the water surface individually or in mats. Plant diameter ranges from 1/3 to 1 inch (1–2.5 cm) for small species, such as *Azolla pinnata*, to 6 inches (15 cm) or more for *A. nilotica*. A shallow fresh-water pond, is the ideal environment for azolla.

Climate and Growth Requirement

Azolla is found in ponds, ditches, and wetlands of warm temperate and tropical regions throughout the world. It must grow in water or wet mud, and it dies within a few hours

underdry conditions. Azolla can survive a water pH range of 3.5–10, but optimum growth occurs when the water is between pH 4.5 and 7. The optimum temperature for azolla is between 64 and 82°F (18–28°C). The growth rate gradually declines as salinity increases. Azolla grows in full to partial shade (100–50% sunlight), with growth decreasing quickly under heavy shade. Azolla is established by vegetative propagation. Nursery ponds are generally used to supply a large enough volume to a wetland field to ensure quick coverage. **Water:** fresh water 10-15 cm in the multiplication pond, adequate water level in the pond is 4 inches **Temperature:** Day/night ranges between 32-30 degrees are most favorable for a luxurious growth of azolla temperatures of 23-30 degree centigrade. **Light:** Azolla grows well under partial shade, **Relative humidity:** 85-90%, **Soil PH:** azolla grows well in slightly acidic soil: 5.2-5.8 and **Nutrition:** being a nitrogen fixing fern, azolla doesn't require nitrogenous fertilizer for its growth. (phosphorus 20kg/ha is desirable for good biomass production).

Azolla As a Animal Feed

The nutrient constitution of Azolla is found to be almost similar to that of commercial poultry feed, except that the protein content is high and calcium content is slightly low. There will be a substantial improvement in the quantity, as well as, quality of milk produced, when dairy cattle are fed with Azolla combined with commercial feed along with an improvement in the health of the cattle. The increase in the milk yield is to the tune of 10–15%, which went up to 20%, during summer months from February to May. It is found that the increase in the quantity of the milk produced on the base of nutrient was higher than the quantity of Azolla fed. Hence, it is assumed that more than the carbohydrate, protein content and other components, like carotinoids, biopolymers, probiotics etc., may be contributing to the overall increase in the production of milk.

Azolla Production

1. An artificial water body is made, preferably under the shade of a tree, with the help of a silpauline sheet.
2. A pit of the size of 2M X 2M X 0.2M is dug as a first step.
3. This pit is covered with plastic gunnies to prevent the roots of the nearby trees piercing the silpauline sheet, which is spread over the plastic gunnies.
4. About 10–15 kg of sieved fertile soil is uniformly spread over the silpauline sheet.
5. Slurry made of 2-kg cow dung and 30 gms of Super Phosphate in 10 litres water, is poured

onto the sheet.

6. More water is poured to make the water level reach about 10 cm.
7. About 500g to 1kg of fresh and pure culture of Azolla is inoculated in the pit.
8. Azolla will rapidly grow and fill the pit within 10-15 days and about 500 - 600g of Azolla can be harvested daily thereafter.
9. A mixture of 20 g of Super Phosphate and about 1 kg of cow dung should be added once in 5 Days.
10. This is done to keep the Azolla in rapid multiplication phase and to maintain the daily yield of 500g /pit.
11. Micronutrient mix containing magnesium, iron, copper, sulphur etc., can also be added at weekly intervals to enhance the mineral content of Azolla.

Pond Maintenance

1. Add nutrient to the pond once every two to three weeks
2. Any litter or aquatic plants should be removed regularly
3. The pond need to be emptied once in every 6 months and cultivation started with soil and new azolla culture

Harvesting and Feeding Azolla

After 10-14 days, the Azolla will cover the whole pond and harvest it on 15th day (this will depend on the quality of culture used, climatic condition and nutrient level) Harvest Azolla by scooping it off from the pond by hand or using a plastic sieve. azolla can be fed to livestock in fresh, or dry form. It can be fed directly or with other concentrates. Azolla has to be cleaned thoroughly in clean water to remove cowdung smell Shade your pond to prevent direct sunlight; it turns brownish reddish and lowers nutrient levels.

Economic value

On dry weight basis Azolla contains the following chemical compositions

S.No	Nutritional Content	Azolla
1	Crude protein (%)	23.07
2	Crude fiber (%)	13.19
3	Crude fat (%)	3-3.5
4	Nitrogen%	5

5	Sugar (%)	3.4-3.5
6	Calcium (%)	0.1-1
7	Total Ash (%)	10
8	Phosphors (%)	0.5
9	Iron (%)	0.26
10	Sodium (%)	1.24
11	Potassium (%)	2-4.5
12	Copper (ppm)	17
13	Zinc (ppm)	66
14	Magnesium (%)	0.16
15	Moisture (%)	5
16	Starch (%)	6.5
17	Chlorophyll (%)	0.34-0.55

Limitation of Azolla

1. Water is prerequisite for Azolla production
2. Extremely low temperature is not suitable
3. Initial cost is slightly highly
4. Ignorance on the importance of Azolla

Precautions

1. A shady place, preferably under a tree, with sufficient sunlight should be chosen for the Azolla production unit. A place of direct sunlight should be avoided.
2. All corners of the pit should be of the same level so that the water level can be maintained uniformly.
3. Azolla biomass @ 300 -350g /sq.meter should be removed daily to avoid overcrowding and for keeping the fern at rapid multiplication phase.
4. Suitable nutrients should be supplied, as and when, nutrient deficiency is noticed.
5. Plant protection measures against pests and diseases should be taken as and when required,
6. About 5 kg bed soil should be replaced with fresh soil, once in 30 days, to avoid nitrogen build up and prevent micro-nutrient deficiency.
7. 25 to 30% water also needs to be replaced with fresh water, once in 10 days, to prevent nitrogen build up in the bed.
8. Replacement of water and soil should be followed by fresh inoculation of Azolla, at least once



in six months.

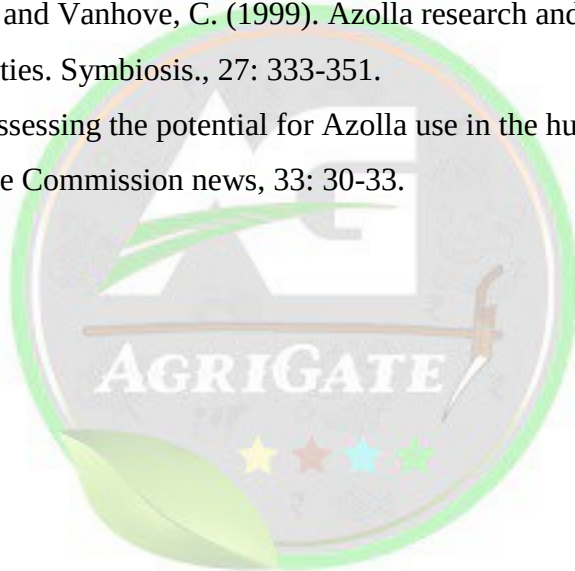
9. A fresh bed has to be prepared and inoculated with pure culture of Azolla, when contaminated by pest and diseases.

Conclusion

Azolla can be used as an ideal feed substitute for cattle, fish, pig and poultry and also utilize as a biofertilizer for crops. Azolla technology will be taken up in a big way by the dairy farmers.

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AI-DRIVEN PREDICTIVE ANALYTICS FOR FOOD FRAUD PREVENTION

Article ID: AG-VO5-I05-108***Irfan Khan¹, Akanksha Soni² and Devinder Kaur³**¹Department of Bioengineering, Integral University, Dasauli, Lucknow, India-226026^{2,3}Centre of Food Technology, University of Allahabad, Prayagraj, India-211002*Corresponding Author Email ID: khan.irfan380@gmail.com

Abstract

Food fraud, encompassing economically motivated adulteration and misrepresentation, poses significant threats to public health, consumer trust, and the integrity of global food supply chains. Traditional detection methods often fall short due to their reactive nature and limited scalability. This article explores the transformative role of Artificial Intelligence (AI)-driven predictive analytics in proactively identifying and mitigating food fraud risks. By leveraging machine learning algorithms, AI systems can analyze vast and diverse datasets—including historical incidents, supply chain records, and environmental factors—to detect patterns indicative of fraudulent activities. The integration of federated learning approaches addresses data privacy concerns, enabling collaborative model training across organizations without compromising sensitive information. Furthermore, the synergy between AI, Internet of Things (IoT) devices, and blockchain technology enhances real-time monitoring and traceability, ensuring transparency from farm to table. Through case studies and current implementations, this article highlights the efficacy of AI-driven predictive analytics in fortifying food safety protocols and underscores its potential as a cornerstone in the fight against food fraud.

Keywords: Food fraud, food safety, artificial Intelligence, blockchain technology

Introduction

Food fraud, encompassing the deliberate substitution, addition, tampering, or misrepresentation of food, food ingredients, or food packaging, poses significant threats to public health, consumer trust, and the global food economy. Incidents such as the melamine-tainted

milk scandal in China and the horsemeat substitution in Europe have underscored the vulnerabilities within complex food supply chains. Traditional methods of detecting food fraud, often reactive and reliant on manual inspections, are increasingly inadequate in addressing the sophisticated tactics employed by fraudsters.

The advent of Artificial Intelligence (AI) offers a transformative approach to combating food fraud. By leveraging vast datasets and advanced algorithms, AI-driven predictive analytics can identify patterns and anomalies indicative of fraudulent activities before they impact consumers. This proactive stance not only enhances food safety but also reinforces consumer confidence and protects brand integrity.

AI's application in food fraud prevention encompasses various technologies:

- **Machine Learning (ML):** ML algorithms can analyze historical data to predict potential fraud risks, enabling preemptive actions. RDR Global Partners
- **Computer Vision:** AI-powered image recognition systems can detect visual inconsistencies in food products, identifying adulteration or mislabeling. PublicSphereTech
- **Natural Language Processing (NLP):** NLP tools can scrutinize textual data, such as labels and certificates, for inconsistencies or fraudulent claims. PublicSphereTech
- **Integration with IoT and Blockchain:** Combining AI with Internet of Things (IoT) devices and blockchain technology enhances traceability and transparency across the supply chain.

For instance, AI systems can monitor temperature and humidity data from IoT sensors during transportation, ensuring optimal storage conditions and reducing spoilage risks. Simultaneously, blockchain provides an immutable ledger of transactions, allowing stakeholders to trace products from farm to fork, thereby deterring fraudulent activities.

Despite the promising potential of AI in food fraud prevention, challenges persist. Data quality and availability remain significant hurdles, as AI models require extensive and accurate datasets to function effectively. Additionally, integrating AI solutions into existing infrastructures can be complex and resource-intensive. Ethical considerations, such as data privacy and algorithmic transparency, also necessitate careful deliberation. PublicSphereTech

This article delves into the multifaceted role of AI-driven predictive analytics in food fraud prevention. It explores current applications, benefits, challenges, and future directions, providing a comprehensive overview of how AI can fortify the integrity of the global food supply chain.

Understanding Food Fraud

Food fraud refers to the intentional deception of consumers through the adulteration, misrepresentation, or tampering of food products for economic gain. This malpractice can occur at any stage of the food supply chain, from production to distribution, and encompasses various fraudulent activities. Common types include adulteration (adding inferior substances to food), substitution (replacing a high-value ingredient with a lower-cost alternative), dilution (reducing the quality of a product by adding water or other fillers), mislabeling (providing false information on packaging), and counterfeiting (producing imitation products that mimic genuine ones). Notable examples of food fraud include the addition of melamine to milk to falsely elevate protein content, the substitution of horse meat for beef in meat products, and the dilution of olive oil with cheaper vegetable oils. Such fraudulent practices not only compromise consumer trust but also pose significant health risks, especially when allergens or harmful substances are involved. The global nature of food supply chains further complicates detection and prevention, underscoring the need for advanced monitoring and verification systems to safeguard food integrity.

The Role of Predictive Analytics in Food Fraud Prevention

Predictive analytics plays a pivotal role in the proactive prevention of food fraud by leveraging historical and real-time data to forecast potential fraudulent activities within the food supply chain. By analyzing patterns and anomalies in vast datasets, AI-driven predictive models can identify vulnerabilities and emerging threats before they materialize, enabling stakeholders to implement targeted interventions. For instance, platforms like FOODAKAI utilize AI-powered predictive analytics to provide insights into emerging risks, allowing companies to take proactive measures to safeguard their supply chains. This approach marks a significant shift from traditional reactive methods, offering a more dynamic and anticipatory strategy to combat food fraud. The integration of predictive analytics into food fraud prevention strategies enhances the ability to detect subtle indicators of fraudulent activities that might otherwise go unnoticed. By continuously learning from new data inputs, these AI systems adapt to evolving fraud tactics, ensuring sustained efficacy over time. Moreover, the application of predictive analytics extends

beyond detection, contributing to improved risk management and resource allocation by prioritizing areas with higher fraud susceptibility. As the food industry continues to embrace digital transformation, the adoption of predictive analytics stands as a critical component in fortifying the integrity and safety of global food systems.

AI Techniques for Detecting Food Fraud

Artificial Intelligence (AI) has emerged as a formidable ally in the fight against food fraud, employing a suite of sophisticated techniques to detect and prevent adulteration and misrepresentation in food products. Machine Learning (ML) algorithms, for instance, can analyze vast datasets encompassing transaction records, supplier information, and product ingredients to identify patterns and anomalies indicative of fraudulent activities. These algorithms can flag discrepancies such as sudden changes in pricing or ingredient sourcing, which are common red flags for adulteration. In addition to ML, computer vision technologies have been instrumental in identifying visual inconsistencies in food products. By analyzing images of food items, these systems can detect signs of tampering or substitution that might be imperceptible to the human eye. For example, digital image analysis of histological cuts has been used to detect meat adulteration, providing a non-invasive and efficient method for ensuring product authenticity. Furthermore, electronic nose (E-nose) systems, which mimic human olfaction, have been utilized to detect volatile compounds associated with specific food products. By analyzing the aroma profiles of food items, E-nose devices can identify deviations from standard profiles, indicating potential adulteration or spoilage.

Explainable AI (XAI) techniques, such as Local Interpretable Model-agnostic Explanations (LIME) and SHapley Additive exPlanations (SHAP), have also been applied to enhance the transparency and interpretability of AI models in food fraud detection. These methods allow stakeholders to understand the decision-making processes of AI systems, fostering trust and facilitating regulatory compliance.

By integrating these AI techniques, the food industry can proactively identify and mitigate risks associated with food fraud, ensuring the safety and integrity of food products throughout the supply chain.

- Computer vision for visual inspection
- Chemical analysis using AI algorithms
- Natural Language Processing (NLP) for document verification

- Integration of multiple AI techniques for comprehensive detection

Integration of AI with Emerging Technologies

The integration of Artificial Intelligence (AI) with emerging technologies such as the Internet of Things (IoT) and blockchain is revolutionizing the approach to food fraud prevention, enhancing transparency, traceability, and real-time monitoring across the food supply chain. IoT devices, including smart sensors and RFID tags, collect continuous data on environmental conditions like temperature, humidity, and storage duration. AI algorithms process this data to detect anomalies indicative of potential fraud or spoilage, enabling swift corrective actions. Blockchain technology complements this system by providing an immutable ledger that records every transaction and movement within the supply chain. This ensures that all stakeholders—from producers to consumers—have access to verifiable information about the origin, handling, and journey of food products. The synergy between AI and blockchain not only enhances the detection of fraudulent activities but also fosters trust among consumers by ensuring product authenticity. Moreover, the convergence of AI, IoT, and blockchain technologies addresses critical challenges in sustainability and safety within the food industry. By enabling real-time data analysis and secure information sharing, these integrated systems facilitate proactive decision-making and efficient resource management, thereby mitigating risks associated with food fraud.

In summary, the amalgamation of AI with IoT and blockchain technologies offers a robust framework for combating food fraud. This integrated approach not only strengthens the integrity of the food supply chain but also enhances consumer confidence by ensuring the authenticity and safety of food products.

- Combining AI with Internet of Things (IoT) devices
 - Enhancing traceability through blockchain technology
 - Real-time monitoring and data analysis
- [Smart Food Safe+5ScienceDirect+5digitaledition.food-safety.com+5](#)

Benefits of AI-Driven Predictive Analytics

AI-driven predictive analytics offers transformative benefits in combating food fraud by enabling proactive risk detection, enhancing supply chain transparency, and reducing economic losses. Unlike traditional methods that often rely on known adulterants and static testing, AI systems can analyze vast and diverse datasets to identify subtle patterns and anomalies indicative

of fraudulent activities. For instance, platforms like FOODAKAI utilize AI-powered predictive analytics to forecast emerging risks by analyzing historical incidents, laboratory data, and environmental factors, allowing companies to implement preventive measures before issues arise. Moreover, AI technologies facilitate real-time monitoring and assessment of food safety parameters. By integrating with IoT devices, AI can continuously track conditions such as temperature and humidity across the supply chain, ensuring products remain within safe parameters and reducing the likelihood of spoilage or contamination. This continuous oversight enables early detection of potential issues, allowing for immediate intervention and minimizing risks to consumers. Additionally, AI enhances the traceability and transparency of the food supply chain. By combining AI with blockchain technology, stakeholders can access immutable records of every transaction and movement within the supply chain, ensuring the authenticity and integrity of food products. This level of transparency not only deters fraudulent activities but also fosters consumer trust by providing verifiable information about the origin and handling of food items. In summary, the integration of AI-driven predictive analytics into food fraud prevention strategies enables a shift from reactive to proactive approaches, enhancing the ability to detect and mitigate risks, ensuring product authenticity, and safeguarding public health.

Challenges and Considerations

Implementing AI-driven predictive analytics for food fraud prevention presents several challenges and considerations that stakeholders must address to ensure effectiveness and ethical compliance. A primary concern is data quality and availability; AI models require extensive, high-quality datasets to accurately detect fraudulent patterns. However, the food industry's reluctance to share proprietary information and the lack of standardized data formats hinder the development of robust AI systems. Additionally, the interpretability of AI models poses a significant challenge. Many machine learning algorithms operate as "black boxes," making it difficult for users to understand the rationale behind specific predictions. This opacity can impede trust and acceptance among stakeholders. Ethical considerations also play a crucial role in the deployment of AI technologies. The use of AI for monitoring supply chains raises concerns about data privacy and surveillance, necessitating a balance between transparency and the protection of sensitive information. Furthermore, the integration of AI systems into existing infrastructure can be resource-intensive, requiring significant investment in technology and personnel training. Regulatory frameworks have yet to catch up with the rapid advancement of

AI, leading to uncertainties regarding compliance and accountability . Addressing these challenges is essential for the successful implementation of AI in food fraud prevention, ensuring that technological advancements translate into tangible improvements in food safety and integrity.

Future Perspectives

The landscape of food fraud prevention is poised for significant transformation as artificial intelligence (AI) continues to evolve and integrate with emerging technologies. Looking ahead, several key developments are expected to shape the future of AI-driven predictive analytics in combating food fraud. The effectiveness of AI models in detecting food fraud hinges on the quality and consistency of data. Future advancements will likely focus on developing standardized data formats and protocols across the food supply chain, facilitating seamless integration of diverse data sources. This will enable more accurate and reliable predictive analytics, enhancing the ability to identify fraudulent activities proactively. As machine learning techniques advance, AI models will become more sophisticated in detecting complex patterns indicative of food fraud. The application of deep learning and other advanced algorithms will allow for the analysis of vast and intricate datasets, improving the accuracy and efficiency of fraud detection systems. The future of food fraud prevention will likely involve real-time monitoring systems powered by AI and Internet of Things (IoT) technologies. These systems will continuously collect and analyze data from various points in the food supply chain, enabling immediate detection of anomalies and prompt responses to potential fraud incidents. To foster trust and facilitate regulatory compliance, the development of explainable AI models will be crucial. XAI aims to make AI decision-making processes more transparent and understandable to humans, allowing stakeholders to comprehend how fraud detection decisions are made and ensuring accountability in AI applications. Addressing food fraud effectively will require collaboration among various stakeholders, including food producers, regulators, and technology providers. The establishment of global standards and shared databases will enhance the collective ability to combat food fraud, ensuring consistency and reliability across different regions and markets. As AI technologies become more integrated into food fraud prevention, ethical and regulatory considerations will become increasingly important. Ensuring data privacy, addressing biases in AI models, and complying with international regulations will be essential to maintain the integrity and public trust in AI-driven systems.

In conclusion, the future of AI-driven predictive analytics in food fraud prevention holds promising prospects. By focusing on data standardization, advancing machine learning models, enabling real-time monitoring, developing explainable AI, fostering collaboration, and addressing ethical considerations, the food industry can strengthen its defenses against fraud and ensure the safety and authenticity of food products worldwide.

Conclusion

The integration of Artificial Intelligence (AI) into predictive analytics represents a transformative shift in the fight against food fraud, enabling proactive detection and prevention strategies that were previously unattainable. By harnessing vast datasets, AI models can identify subtle patterns and anomalies indicative of fraudulent activities, allowing stakeholders to address potential threats before they escalate. The application of AI techniques such as machine learning, deep learning, and natural language processing has proven effective in analyzing complex data from diverse sources, including transaction records, supply chain information, and consumer behavior. These advanced models facilitate the identification of emerging fraud trends, offering a dynamic approach to safeguarding food integrity. Furthermore, the synergy between AI and emerging technologies like blockchain and the Internet of Things (IoT) enhances the transparency and traceability of food products throughout the supply chain. Blockchain ensures immutable records of transactions, while IoT devices provide real-time monitoring of environmental conditions, collectively fortifying the defense against food fraud.

Despite the promising advancements, challenges remain in the widespread adoption of AI-driven predictive analytics. Issues such as data privacy concerns, the need for high-quality datasets, and the interpretability of AI models must be addressed to ensure ethical and effective implementation. In conclusion, AI-driven predictive analytics offers a powerful tool in the ongoing battle against food fraud. By embracing these technologies and addressing associated challenges, the food industry can enhance food safety, protect consumer health, and maintain public trust in the integrity of food products.

BREAKING THE TERMINAL MOLD: LATERAL FRUITING HOLDS THE KEY TO FUTURE-READY MANGO ORCHARDS

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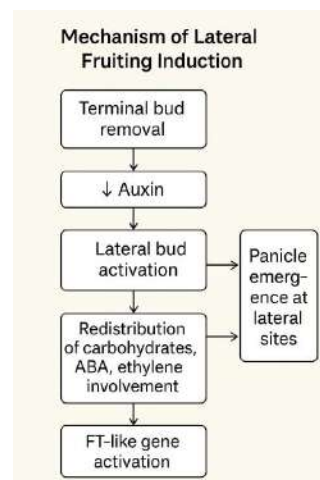
Introduction

As the mango industry navigates the demands of a growing global market, a quiet but crucial transformation is underway—one that could redefine how we grow this king of fruits. While high-density planting (HDP) has become the buzzword for modern horticulture, its success in mango orchards remains constrained by a biological quirk: the tree's terminal bearing habit. Unlike many temperate fruit trees, mango flowers—and thus fruits—emerge almost exclusively from the ends of branches. This “terminal” bearing pattern poses a major bottleneck in HDP systems, where smaller, closely spaced trees must yield more per unit area. But there's the possibility: **inducing lateral fruiting**, or encouraging flowering from side buds instead of only at shoot tips, has the potential to overcome this limitation and unlock a new era of mango productivity.

Why Terminal Fruiting Limits HDP Success

In HDP systems, trees are kept compact through regular pruning. While this makes orchard management easier, it also cuts off the terminal ends—the very sites where mangoes bear fruit. The result? Fewer flowering points, irregular fruiting, and a lopsided canopy where most fruits cluster at the top, leaving the lower parts of the tree underutilized.

Moreover, the lack of uniform fruiting hampers mechanized operations and increases labor for selective harvesting. It's an



unsustainable model for future-oriented, high-throughput mango production.

The Case for Lateral Fruiting

Imagine a mango tree that fruits not just at the tips but all along its branches—top, middle, and bottom. That's what lateral fruiting can offer. By triggering flowering from axillary (side) and epicormic (inner) buds, we can expand the fruiting zone, enhance yield potential, and foster uniform canopy productivity. This isn't just a theoretical idea—emerging research and field results are starting to back it up.

The key lies in manipulating plant physiology. When the terminal bud is pruned, apical dominance (the suppressive effect of the top bud) is broken. Hormones like auxin drop, while others like cytokinins and abscisic acid rise, prompting lateral buds to "wake up." Add a touch of water stress or cool weather—both known **flowering triggers** in mango—and these side buds can transition into fruit-bearing shoots.

Science Supports It

Modern studies show that floral signals like FT (FLOWERING LOCUS T) genes—long believed to operate mainly in terminal buds—are actually distributed throughout the shoot. This means lateral buds already hold flowering potential; they just need the right hormonal and environmental cues to express it. Our trials further show that shallow pruning (removing just 10 cm of shoot) results in better lateral panicle emergence than deeper cuts. Why? Because it retains more of the stored floral signals and carbohydrate reserves necessary for flowering.

The Way Forward: A Lateral Strategy for a Vertical Problem

To mainstream lateral fruiting in mango, both growers and researchers must adopt a paradigm shift in orchard design and canopy management. The following interventions are critical:

- **Timed Pruning:** Strategic shallow pruning—specifically the removal of terminal buds just before (0 to 15 days) the natural period of panicle emergence—can effectively redirect energy to activate lateral buds.
- **Irrigation Push:** A timely irrigation immediately after shallow pruning acts as a physiological signal that enhances panicle emergence from lateral buds.
- **Growth Regulator Support:** Application of select growth-regulating compounds post-pruning can suppress excessive vegetative flushes, further promoting floral emergence along lateral shoots.



Conclusion

Lateral fruiting is not merely a physiological phenomenon—it represents a transformative opportunity for mango cultivation. It offers a practical pathway to make high-density planting (HDP) systems more productive, sustainable, and future-ready. The time is ripe to turn this innovation into a new norm. If HDP was the first leap in modern mango orcharding, lateral fruiting is the next one. And this leap may just be the one that takes mango farming from good to truly great





“WHY SEED QUALITY IS THE FOUNDATION OF PROFITABLE FARMING”

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Introduction

In farming, success begins with a single seed. But not just any seed - a quality seed. Often overlooked, the quality of seeds sown by farmers plays a crucial role in determining crop yield, income, and overall agricultural sustainability. Unfortunately, many farmers still use low-quality or uncertified seeds, unknowingly setting themselves up for failure. Seeds form the fundamental basis of any crop. If this foundation is weak, i.e., if seed quality is poor, it adversely affects the entire cultivation process. Unfortunately, due to lack of awareness or the temptation of low prices, many farmers opt for uncertified and substandard seeds that fail to meet quality benchmarks. Such seeds often result in low germination rates and uneven plant development, which disrupts plant density and field uniformity, factors critical to optimal crop performance.

In many cases, these inferior seeds harbor latent pathogens or insect pests, which, once introduced into the field, can spread rapidly and cause significant crop damage. Moreover, crops grown from such seeds generally possess poor yield potential and are poorly adapted to local climatic and soil conditions. Contamination with weed seeds or seeds of other crops is also common, leading to undesirable competition within the field. Crops derived from low-quality seeds often exhibit inconsistent maturity, making harvesting and marketing operations more difficult and less efficient. Farmers are forced to invest more in plant protection measures, fertilizers, irrigation, and labour, which raises input costs while diminishing profitability. In extreme cases, the financial loss may negate the entire year's efforts. Repeated failures of this

nature can severely impact a farmer's confidence and may lead to reluctance in adopting modern agricultural technologies.

Thus, the use of substandard seeds not only reduces yield but also jeopardizes the farmer's livelihood and long-term sustainability. Therefore, seed selection must be approached with caution. Farmers should procure seeds only from certified sources and always follow scientifically backed recommendations to ensure that their efforts translate into productive and profitable outcomes.

Studies suggest that the use of low-quality seeds can lead to a yield loss of 20–30% or even more. To put this into perspective, let's consider a wheat farmer cultivating one hectare of land:

With quality seeds:

Average yield = 4.0 tons/ha

Market price = ₹25,000/ton

Total income = ₹1,00,000

With low-quality seeds (25% yield loss):

Average yield = 3.0 tons/ha

Total income = ₹75,000

Loss due to low-quality seeds = ₹25,000 per hectare.



This loss is often larger than the cost difference between certified and uncertified seeds. In other words, trying to “save” a few hundred rupees by buying cheaper seeds could actually cost the farmer thousands in reduced yields. A quality seed not only contributes to increased crop yield but also ensures sustainable, profitable, and disease-resistant agriculture. For a seed to be considered of high quality, it must possess several critical attributes.

Firstly, a high germination rate is essential. Certified seeds typically exhibit a germination percentage of 85% or higher, which leads to uniform and dense plant populations, which are the key factors in achieving optimal crop performance. Secondly, genetic purity is a fundamental trait of quality seeds. Such seeds are genetically true-to-type and exhibit the characteristics of their parent variety without admixture or contamination, ensuring the crop expresses desirable traits such as high yield, resistance to diseases, and adaptability to environmental stress.



Freedom from pests and diseases is another hallmark of quality seeds. Certified seeds are processed and stored under controlled conditions to eliminate seed-borne pathogens and insect pests, thereby reducing the likelihood of early-stage crop infections. Physical purity is equally important; quality seeds are free from inert matter such as soil, stones, plant debris, weed seeds, or seeds of other crops. This minimizes the risk of field contamination and unwanted plant competition.

Adaptability to local agro-climatic conditions enhances the effectiveness of quality seeds. Seeds selected or developed for specific regions—taking into account local soil type, temperature, and rainfall patterns—demonstrate stable performance under varying conditions. Furthermore, uniformity in plant growth characteristics such as height, maturity, and yield potential simplifies field management and facilitates efficient harvesting and marketing.

Conclusion

However, optimal moisture content and high seed vigour are also essential for maintaining viability during storage and ensuring successful germination, even under suboptimal field conditions. Together, these attributes make it clear that a quality seed is not merely an agricultural input but a strategic investment. It lays a strong foundation for the crop cycle, enabling farmers to cultivate with greater confidence. In the broader context, the use of high-quality seeds supports enhanced productivity, sustainable agriculture, and improved economic outcomes for the farming community.

CHARACTERIZATION AND TYPES OF STOCK IN FISHERIES

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Introduction

A stock is a subset of species, which is considered as the basic taxonomic unit having same growth and mortality parameters which shares the common gene pool. It gives the ability to distinguish between different species. One essential feature is that the growth and mortality parameters remain constant over the distribution area of stock, so we can use them for assessments. It is a group of fish that is genetically and ecologically distinct from other populations. This is often determined by geographic location, spawning grounds, and migratory patterns. Characterizing a stock means identifying and describing the specific attributes of a group of fish that live in the same area and interbreed. This characterization is crucial for understanding the dynamics of a fish population and for making informed management decisions.

Stock characterization in fish stock assessment

- Defining the stock area, its distribution, spawning grounds, stock abundance, migration patterns and further data analyzed contributes to the stock characterization.
- Learning about age from analyzing the hard parts like the scales and otolith in fishes, shells in molluscs and the vertebrae of sharks and growth pattern is also analyzed to learn about the life traits and their interactions with the environment.
- Length –frequency data is used to determine the fish stock with respect to the growth of the individuals with respect to the increase in length from one year to the other following years.
- Tagging and marking the individuals to estimate the fish abundance, movement, growth and mortality.

Reproduction indices gives us the information about the maturation stage, fecundity and spawning rate of the fish

- By analyzing the food content present in the gut can give information about the food web, species interactions and to assess their interactions with the environment.
- Learning about the genetic variation between different stocks and analyzing the phenotypic variations between different stocks for ensuring efficient formation of fisheries management policies for the defined stock.

The need of stock characterization in fisheries management

- Fisheries tend to collapse because of fleet over-capacity, leading to harvesting the stocks of fish beyond their ability to recover. To assess the fishing fleet capacity is one of the objective of fisheries management so the need of stock characterization is very crucial.
- On the other hand, fish stocks may also be under-utilized because of fleet under-capacity. This is particularly the case when fleets are artisanal, in initial stages of development, or with poor infrastructure facilities. When fish stocks are under-utilized because of fleet under capacity there is loss of economic diversification, revenue, employment and food security. So here comes the play of the other objective of management is by learning the different aspects of the particular stock to regulate the management plans needed to improve the stock status and to maintain it in a sustainable way for the future.
- Sometimes when the prices of sea food are usually higher because domestic supply may not meet the demand. Due to the reasons mentioned above, fisheries management must strike a balance between over-exploitation and under exploitation . The risk of over-exploitation is the risk of management inaction, letting fishermen take too many fish from the sea thereby negatively impacting the sustainability of the stock and the fishing industry. The risk of under-exploitation is the risk of excessive management interference, setting too many obstacles to the fishermen to take fish. The fishery manager has to strike a balance by directly controlling the fishing capacity (input control) and/or by setting restrictions on the catch (output control).

To formulate fisheries management plan corresponding to the different parameters of the stock will effectively help to manage and replenish the overexploited stocks which has been assessed and characterized.

Types of stock

- Unit stock
- Mixed stock
- Shared stock – Trans boundary stock
 - Straddling stock
 - Highly migrating stock

Unit stock

- A unit stock can be theoretically described as a group of individuals of the same species whose gains by immigration and whose losses by emigration.
- A unit stock is essentially a self-contained population with its own spawning area. Gene exchange within stocks having same growth patterns and mortality rates. They should have same morphometric ,meristic characteristics ,spawning patterns and season.
- Example : Aroto Norwegion Cod, This spawns inside the Lofoten Islands, northern Norway; the eggs and fry are carried in the North Atlantic drift to Spitzbergen and into the Barents Sea, both of the areas forming the nursery grounds.

Mixed stock

- Mixed stock fishery is a fishery whose stock consists of fish that are of a variety of ages, sizes, species, geographic or genetic origins or any combination of these variables.
- Mixed stock of a species has significant differences in morphological and biological characteristics.
- Mixed stock of a species has varied spawning seasons and the calculation of length at minimum maturity and growth gets varied.

Example : Sock eye salmon fisheries in Bristol Bay, Atlantic cod fisheries in Greenland.

Shared stock

- Shared stocks can be classified into three non-exclusive categories;

Transboundary stocks

Stocks which occur within the exclusive economic zone of two or more coastal states.

Example: Peruvian anchoveta and herring.



Straddling stocks

Stocks which occur both within and beyond the exclusive economic zone of a single coastal state.

Example: Alaska pollock, Cod , Flounder, Turbot.

Highly migratory stock

Stock that migrates long distance across the international waters.

Example: Tuna, marlin, swordfish.

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STUDY ON THE EFFECT OF *PINK PIGMENTED FACULTATIVE METHYLOTROPHS* (PPFM) ISOLATES ON THE GROWTH AND YIELD OF BLACK GRAM VAR. MDU 1

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ABSTRACT

Methylobacterium sp. are gram negative and rod shaped alpha- proteobacteria able to grow on C1 compounds such as formate, formaldehyde, methanol, methylamine as well as variety of C2, C3 , C4 compounds via., serine pathway as their carbon and energy sources. Pink Pigmented Methylobacteria (PPFMs) are gaining momentum as impart drought tolerance and promote the growth of the plants through cytokinin production. PPFM could be used to mitigate the drought in pulses. Blackgram (*Vigna mungo* (L.) is one of the most important food legumes among the pulses in India. A study was undertaken to isolate Pink Pigmented Facultative Methylobacteria (PPFM) from pulses and their effect on Black gram. The leaf samples were collected from the different pulse crops (Blackgram, greengram, redgram and cowpea) from various locations of southern regions of Tamil Nadu (Vamban, Madurai, Kovilpatti and Chettinadu) and totally 49 PPFM isolates were isolated. The 49 isolates screened based on their ARA activity and 11 efficient isolates were selected for further field study. These selected isolates were further studied for their inoculation effect on blackgram under field condition with Blackgram cv. MDU 1. Among the different treatments, the treatment T₄ (GGKF2) showed significant increase in root and shoots length, number of nodules and increased yield of 788 Kg ha⁻¹ compared to the uninoculated control.

Key words: *Pink Pigmented Facultative Methylobacteria* (PPFM), *Blackgram*

INTRODUCTION

Pulses are the main source of protein for majority of the people in our country. On an average pulses contain 20 - 25 per cent protein on dry weight basis, which is almost 2.5 - 3.0 times that of a cereal. As a restorative crop of soil fertility, pulses have a unique position in cropping systems of wet land, dry land and garden land agriculture. The heavy leaf drop increases the organic matter content in soil and pulses can also fix higher amount of atmospheric nitrogen through microbial symbiosis and thus minimize the dependency on chemical fertilizers. Apart from this they are well adapted to low fertility and limited soil moisture conditions due to its proliferated root system.

Pulses occupy 68.30 million ha of area and contribute 57.5 million tonnes to the world's food basket in Tamil Nadu. Pulses are cultivated under rice fallow conditions in about 2.60 lakh ha in Tamil Nadu, which is 30.75 per cent of the total area under pulses and the fallow pulses contribute around 40.50 per cent of the total pulses production. Pulses are generally grown in soils with low fertility or with application of low quantities of organic and inorganic plant nutrients, which has resulted in deterioration of soil health and low crop productivity (Kumpawat, 2010). Extension of pulses cultivation in non-traditional areas, seasons, growing conditions and crop substitutions are the major avenues for area expansion (Ali, 1997; Ali and Kumar, 2000 and Ramasamy and Selvaraj, 2002). The other conventional strategies for increasing the production of pulses includes utilization of improved varieties, production technologies and plant protection measures which are expected to reduce the existing gap in production and requirement.

Blackgram (*Vigna mungo* (L.) is one of the most important food legumes among the pulses in India. The Blackgram can be grown in more diverse environments with an average productivity of 642 kg ha⁻¹ and efforts could be initiated for its expansion in new niches (Joshi and Saxena, 2002). The interactions between these microorganisms and higher plants frequently affect the physiological activities of the plant (Holland et al., 2002 and 2011). The facultative methylotrophic bacterium belonging to the genus *Methylobacterium* popularly called as PPFM (Pink Pigmented Facultative Methylophs) found to colonize the plant surface ubiquitously (Holland and Polacco, 1994). The consistent success of methylotroph strains in colonizing the phyllosphere is probably due to their ability to utilize methanol as carbon and energy source which cannot be utilized by other microorganisms. *Methylobacterium* sp. are gram negative and

rod shaped alpha- proteobacteria able to grow on C1 compounds such as formate, formaldehyde, methanol, methylamine as well as variety of C2, C3 , C4 compounds via., serine pathway as their carbon and energy sources.

Blackgram being raised mostly under rainfed condition and rice fallow crop suffer due to water stress, as a result the scanty rainfall. Studies reported that under these circumstances recently, Pink Pigmented Methylophs are gaining momentum as impart drought tolerance and promote the growth of the plants through cytokinin production. PPFM could be used to mitigate the drought in pulses. Novel strains of PPFM (Pink Pigmented Facultative Methylophs) were isolated and tested for the efficiency in blackgram under field conditions

MATERIALS AND METHODS

Isolation and purification of Pink Pigmented Facultative Methylophs:

Methanol Mineral Salts (MMS) or Ammonium Mineral Salts (AMS) medium (Whittenbury *et al.*, 1970) is the selective medium for isolation of methylophs. The AMS medium was sterilized by autoclaving at 121° C for 20 minutes and cooled to 50° C .The cooled AMS media was supplemented with 0.5 % methanol and 0.1 % filter sterilized cyclohexamide. The pH of the medium was adjusted to pH 6.8 with acid or alkali. Isolation was done by adapting the following three methods

1. Leaf imprinting technique (Corpe, 1985)
2. Serial dilution technique (Corpe and Rheem, 1989)
3. Enrichment techniques (Zahra *et al.*, 2004)

1. Leaf imprinting technique (Corpe, 1985)

The dorsal and ventral surfaces of the leaves were imprinted onto the AMS media and after a while, the leaves were removed and the plates were incubated at 28±2° C for 7 days. At the end of the incubation period, colonies showed pink pigmentation were selected for further work.

2. Serial dilution technique (Corpe and Rheem, 1989)

One gram of leaf sample was ground using pestle and mortar, serially diluted up to 10⁻⁶ dilutions and one ml of the aliquot from 10⁻⁴, 10⁻⁵ and 10⁻⁶ dilutions was transferred to the sterile Petridishes and plated with AMS medium. Filter sterilized cyclohexamide (0.1 per cent)

antibiotic solution and 0.5 per cent (v/v) methanol were incorporated into the sterilized AMS medium before plating. The plates were incubated in an inverted position for 5-7 days at $28\pm 2^{\circ}\text{C}$. Characteristic pink colonies growing over the medium were selected (Corpe and Rheem, 1989).

3. Enrichment techniques (Zahra *et al.*, 2004)

Three grams of fresh leaf samples were agitated at 150 rpm at 30°C for 2h in 100 ml Erlenmeyer flasks containing 25 g of glass beads (0.1 cm) and 50 ml of phosphate buffer saline. After agitation, appropriate dilutions of the flask contents were plated onto the AMS medium supplemented with methanol (0.5 %; v/v) and cyclohexamide (0.1 %; 30 $\mu\text{g/ml}$) and the plates were incubated at $28\pm 2^{\circ}\text{C}$ for 5-7 days.

Colonies showing pink pigmentation were further purified and preserved in AMS agar slants. The well maintained AMS slants and glycerol stocks at 4°C under refrigerator condition were used for further study. The 49 isolates were named based on their crop, method of isolation and location.

Morphological characterization (Gerhardt *et al.*, 1981)

The morphological characters of Pink Pigmented Facultative Methylotrophs were identified by following the methods of Gerhardt *et al.* (1981). The colony characters viz., margin, elevation, colour, shape, surface of the colonies were observed as described by Gerhardt *et al.* (1981). All the isolates were examined for their Gram's reaction.

Gram's reaction (Gerhardt *et al.*, 1981)

The Gram's reaction of the Pink Pigmented Facultative Methylotrophs isolates was performed by following the method of Gerhardt *et al.* (1981). Resulted gram staining was confirmed through KOH string test. 10 percent of the KOH is prepared and one to two drops of KOH is placed on the slide followed by loop of culture is suspended in it. In case of Gram negative bacteria, a string will be formed in between glass slide and inoculation loop since the bacterial cell wall gets dissolved in 10 percent KOH whereas in case of Gram positive bacteria no string will be formed as its cell wall won't dissolve in 10 percent KOH

Screening of PPFM isolates for nitrogen fixing efficiency (Hardy *et al.*, 1968)

The nitrogen fixing capacity of isolated strains was evaluated by using acetylene reduction activity (ARA) following the standard procedure. Twenty ml of Ammonium Mineral

salts broth was prepared in 100 ml vials. The vials were inoculated with 2.5 ml of Pink Pigmented Facultative Methylophs isolates were incubated under static condition in an incubator at $28 \pm 2^\circ \text{C}$. After 7 days of incubation the cotton plug were replaced by suba seal septa and tightened with aluminium cap. The air in the vial was replaced with nitrogen gas. Ten per cent (V/V) of the inert gas was removed and 10% pure acetylene gas was injected. The vials were incubated for 24 h at room temperature. After the incubation one ml of gas sample was withdrawn and injected in to the Gas chromatograph fitted with porapack Q coloumn and FID detector. The column temp was maintained at 80°C , nitrogen gas was used as carrier gas at the flow rate of 20 ml min^{-1} . The ARA was expressed as n moles of ethylene formed mg^{-1} protein.

Field Experiment

A field experiment was taken up in the field No.A-4 at the Central Farm of Agricultural College and Research Institute, Madurai to test the efficiency of Pink Pigmented Facultative Methylophs in pulses. The experimental site is located at $9^\circ 54' \text{N}$ latitude and $78^\circ 54' \text{E}$ longitude at an altitude of 147 m above MSL. Further, the zone comes under the Southern agro climatic zone of Tamil Nadu.

Design and Layout of the field experiment

The field study was conducted with blackgram var.MDU 1 raised during *Kharif* season in a Randomised Block Design (RBD) with the following 12 treatments in three replications and experimental field was fragmented into 36 plots, with 12 m^2 ($4 \text{ m} \times 3 \text{ m}$).

- T₁ - 75 % N+ BBLM6+ (100 % P&K)
- T₂ - 75 % N+ BLBC1+ (100 % P&K)
- T₃ - 75 % N+ BLSC1+ (100 % P&K)
- T₄ - 75 % N+ GGKF2+ (100 % P&K)
- T₅ - 75 % N+ BGKF1+ (100 % P&K)
- T₆ - 75 % N+ GLBC1+ (100 % P&K)
- T₇ - 75 % N+ RMLS1+ (100 % P&K)
- T₈ - 75 % N+ RLBV1+ (100 % P&K)
- T₉ - 75 % N+ GGKB1+ (100 % P&K)
- T₁₀ - 75 % N+ GLFC1+ (100 % P&K)
- T₁₁ - 75 % N+ RLFV2+ (100 % P&K)
- T₁₂ - Control (100 % RDF)

Seeds of blackgram var. MDU 1 were treated with *Methylobacterium* strains @ 25 ml per kg of seeds as seed treatment. The seeds were sown with 30 X 10cm spacing in each plot and three replications were maintained for each treatment. Regular watering was done to maintain the optimum soil moisture. Necessary plant protection measures were taken as per the recommended practices.

Biometric observations such as root length and shoot length, number of nodules were taken on 30, 45 and 60 DAS. The number of pods per plant and yield were recorded at the time of harvest

RESULT

Morphological Characterization

All the 49 isolates were observed for the morphological characters such as colony colour, form, elevation and margin. Most of the colonies were pink, pale pink or dark pink in colour due to pigmentation and they were mostly circular, flat and regular. The results of the morphological characters of PPFM isolates are presented in Table 1.

Table 1: Morphological characteristics of the PPFM Isolates

S. No	Isolates	Colony colour	Form	Elevation	Margin	CD (cm)
1.	BBLMI	Light Pink	Small Circular	Flat	Regular	0.1
2.	BBLM2	Red	Small Circular	Flat	Regular	0.2
3.	BBLM3	Light Pink	Small Circular	Flat	Regular	0.1
4.	BBLM6	Pink	Small Circular	Slightly	Regular	0.3
5.	BBLM7	Red	Small Circular	Flat	Regular	0.1
6.	BBLM8	Pink	Circular	Flat	Regular	0.1
7.	BBLV2	Pink	Circular	Flat	Regular	0.2
8.	BBLV4	Light Pink	Circular	Slightly raised	Regular	0.1
9.	BFLV2	Light Pink	Circular	Flat	Entire	0.3
10.	BGKF1	Pink	Circular	Flat	Entire	0.1
11.	BGKF2	Light Pink	Circular	Raised	Regular	0.1
12.	BGKB1	Pink	Circular	Flat	Entire	0.2
13.	BGKF2	Pink	Filamentous	Flat	Erose	0.1
14.	BLBC1	Pink	Circular	Flat	Entire	0.2
15.	BLSK1	Light Pink	Circular	Slightly raised	Regular	0.1
16.	BLSC1	Light Pink	Small Circular	Raised	Regular	0.3
17.	GGMS1	Dark Pink	Circular	Raised	Regular	0.1
18.	GGMS2	Dark Pink	Circular	Flat	Regular	0.3
19.	GGMS3	Light Pink	Small Circular	Flat	Regular	0.2

20.	GGMS5	Dark Pink	Circular	Flat	Entire	0.1
21.	GGMS7	Pink	Circular	Raised	Regular	0.2
22.	GBLMI	Pink	Circular	Raised	Regular	0.1
23.	GBLM2	Pink	Circular	Flat	Regular	0.3
24.	GBLV 1	Pink	Circular	Flat	Regular	0.1
25.	GBLV 2	Pink	Circular	Raised	Regular	0.1
26.	GGKF1	Pink	Circular	Flat	Regular	0.3
27.	GGKF2	Pink	Circular	Flat	Entire	0.1
28.	GGKB 1	Dark Pink	Circular	Flat	Regular	0.1
29.	GLBC 1	Pink	Irregular	Flat	Entire	0.2
30.	GLFC 1	Light Pink	Circular	Flat	Entire	0.1
31.	GLSK 1	Dark Pink	Irregular	Flat	Undulate	0.3
32.	GLSC 1	Light Pink	Circular	Raised	Regular	0.1
33.	RMLS 1	Light Pink	Circular	Raised	Regular	0.1
34.	RMLS 2	Pink	Circular	Raised	Regular	0.2
35.	RLBV 1	Light Pink	Circular	Flat	Regular	0.1
36.	RLFV 2	Light Pink	Circular	Slightly Raised	Regular	0.2
37.	RLBC 2	Pink	Small Circular	Flat	Regular	0.1
38.	RLBC 3	Dark Pink	Circular	Raised	Regular	0.3
39.	RLFC 1	Pink	Circular	Raised	Regular	0.1
40.	RLSC 1	Dark Pink	Circular	Raised	Regular	0.3
41.	CFLM 1	Dark Pink	Circular	Slightly Raised	Entire	0.2
42.	CFLM 2	Light Pink	Circular	Raised	Regular	0.1
43.	CFLM 3	Dark Pink	Large Circular	Flat	Regular	0.2
44.	CFLM 6	Pink	Small Circular	Flat	Regular	0.1
45.	CFLM 7	Light Pink	Circular	Slightly Raised	Regular	0.3
46.	CKB 1	Light Pink	Circular	Slightly Raised	Regular	0.1
47.	CKF 1	Light Pink	Circular	Flat	Regular	0.2
48.	CLSK 1	Pink	Circular	Flat	Regular	0.3
49.	CLSC 1	Light Pink	Filamentous	Flat	Undulate	0.1

Screening of PPFM isolates based on their ARA activity

The influence of PPFM isolates on efficiency of nitrogen fixation is presented in Table 2. The nitrogen fixing ability is ranged from 40.120 ± 0.459 to 688.59 ± 4.659 n mole of ethylene produced $\text{h}^{-1} \text{mg}^{-1}$ of protein. The highest nitrogen fixation was observed in GGKF2 isolate with 688.59 ± 4.659 n mole of ethylene produced $\text{h}^{-1} \text{mg}^{-1}$ of protein while the lowest nitrogen fixing efficiency was recorded in CFLM1 of 40.120 ± 0.459 n mole of ethylene produced $\text{h}^{-1} \text{mg}^{-1}$ of protein.

Table. 2: Estimation of the ARA activity the different PPFM isolates

S.No	Isolates	ARA activity (n mole of ethylene produced h ⁻¹ mg ⁻¹ of protein)	S.No	Isolates	ARA activity (n mole of ethylene produced h ⁻¹ mg ⁻¹ of protein)
1	BBLMI	210.79±0.241	26	GGKF1	387.33±0.022
2	BBLM2	313.36±3.914	27	GGKF2	688.59±0.012
3	BBLM3	354.55±8.303	28	GGKB 1	662.05±0.001
4	BBLM6	494.86±4.378	29	GLBC 1	440.90±0.014
5	BBLM7	121.05±2.646	30	GLFC 1	488.41±0.012
6	BBLM8	269.06±5.601	31	GLSK 1	434.26±0.018
7	BBLV2	330.88±3.272	32	GLSC 1	307.66±0.016
8	BBLV4	180.24±1.126	33	RMLS 1	579.30±0.014
9	BFLV2	314.36±4.908	34	RMLS 2	143.5±0.013
10	BGKF1	441.36±2.297	35	RLBV 1	438.38±1.141
11	BGKF2	221.23±1.612	36	RLFV 2	449.92±3.278
12	BGKB1	172.01±2.328	37	RLBC 2	277.71±2.428
13	BGKF2	268.64±5.592	38	RLBC 3	43.76±0.319
14	BLBC1	416.82±7.809	39	RLFC 1	371.33±9.469
15	BLSK1	237.05±2.714	40	RLSC 1	172.27±3.497
16	BLSC1	586.20±12.813	41	CFLM 1	40.120±0.459
17	GGMS1	426.41±9.321	42	CFLM 2	397.07±0.620
18	GGMS2	322.06±4.190	43	CFLM 3	397.29±2.686
19	GGMS3	297.13±2.938	44	CFLM 6	532.12±6.369
20	GGMS5	259.39±0.026	45	CFLM 7	274.52±6.469
21	GGMS7	493.39±0.018	46	CKB 1	684.16±17.091
22	GBLMI	560.00±0.024	47	CKF 1	505.00±8.147
23	GBLM2	174.36±0.046	48	CLSK 1	468.71±7.074
24	GBLV 1	379.67±0.009	49	CLSC 1	641.92±12.280
25	GBLV 2	255.30±0.022		CD(0.05)	17.92

Based on the ARA activity, the best isolates BBLM 6, BLBC 1, BLSC 1, GGKF 2, BGKF 1, GLBC 1, RMLS 1, RLBV1, GGKB 1, GLFC 1 and RLFV 2 were selected and used for further field experiments

Effect of inoculation of selected PPFM isolates under Field condition

Seed treatment of screened efficient PPFM isolates showed significant influence on root and shoots length of blackgram and results presented in the table 3 as follows

Table. 3: Effect of selected PPFM isolates on Root and shoot lengths of blackgram cv., MDU 1 under field conditions

Treatments	Root length (in cm)			Shoot length (in cm)		
	30 DAS	45 DAS	60 DAS	30 DAS	45 DAS	60 DAS
T₁	13.33 ± 0.90	17 ± 1.35	19.0 ± 0.36	35.33 ± 2.81	41.7 ± 0.12	51.7 ± 0.69
T₂	13.30 ± 0.84	16.50 ± 0.98	18.6 ± 0.02	39.33 ± 2.34	46.4 ± 0.16	50.9 ± 0.79
T₃	13.76 ± 1.52	17.50 ± 1.90	18.8 ± 0.29	36.66 ± 3.99	47.6 ± 1.11	52.2 ± 0.43
T₄	15.72 ± 0.61	20 ± 0.78	22.84 ± 0.34	42.6 ± 1.65	56.8 ± 0.47	61.9 ± 1.29
T₅	12.43 ± 0.86	15 ± 1.03	16.08 ± 0.06	36.33 ± 2.51	47 ± 0.41	59.2 ± 0.92
T₆	12.66 ± 0.86	15.50 ± 0.97	16.87 ± 0.26	33.66 ± 2.11	48.5 ± 0.42	50.9 ± 0.34
T₇	14.02 ± 1.37	18.50 ± 1.90	20.02 ± 0.36	34 ± 3.48	52 ± 1.10	57.6 ± 1.02
T₈	11.33 ± 1.32	14 ± 1.46	15.02 ± 0.17	30 ± 3.13	46.2 ± 0.67	49.8 ± 0.18
T₉	14.10 ± 0.87	19 ± 1.18	20.04 ± 0.07	37 ± 2.29	53.6 ± 0.25	58.7 ± 0.70
T₁₀	13.23 ± 1.00	16 ± 1.20	18.3 ± 0.38	37.66 ± 2.82	46.3 ± 1.10	51.5 ± 0.75
T₁₁	13.96 ± 0.91	18 ± 1.24	19.2 ± 0.22	33.33 ± 2.30	48.2 ± 0.85	52.1 ± 0.65
T₁₂	10.24 ± 0.64	13.50 ± 0.85	12.23 ± 0.17	28 ± 1.75	40.5 ± 0.04	45.8 ± 0.69
SEd	0.74	0.95	0.38	2.00	0.91	1.00
CD	1.57	1.99	0.79	4.19	1.89	2.07

Root and Shoot lengths of blackgram cv., MDU 1 under field conditions

The effect of PPFM isolates on length of root and shoots were found to be significant under field conditions. The root length ranged from 10.24 to 15.72, 13.5 to 20.0, 12.23 to 22.84 cm and the shoot length ranged from 28 to 42.6, 40.5 to 56.8, 45.8 to 61.9 cm at 30, 45 and 60 DAS respectively. Among the different treatments, T₄ (GGKF2) recorded significantly maximum root length of 15.72, 20 and 22.84 cm and shoot length of 42.6, 56.8 and 61.9 cm at 30, 45 and 60 DAS respectively and this was followed by T₉ (CKB1) which recorded the root length of 14.1, 19.0 and 20.04 cm and shoot length of 37, 53.6 and 58.7 cm at 30, 45 and 60 DAS respectively. However, the lowest root length of 10.24, 13.5 and 12.23 cm and shoot length of 28, 40.5 and 45.8 cm were recorded in the treatment T₁₂ (control) at 30, 45 and 60 DAS respectively

Number of nodules and yield of blackgram cv. MDU 1 under field conditions

The Pink Pigmented Facultative Methylophs plays a significant role in Nitrogen fixations which in turn have a direct impact on number of nodules. The number on nodules ranged from 11.2 to 18.6 and 19.2 to 24.8 at 30th and 45th day respectively. Yield is an important attribute which depends on number of pods/plant, number of seeds/ pod. PPFM had a significant influence on the yield of blackgram for which the results are given in Table 4

Table. 4: Effect of selected PPFM isolates on number of nodules and yield of blackgram cv., MDU 1 under field conditions

Treatments	Number of nodules		Grain Yield (kg/ ha)
	30 DAS	45 DAS	
T ₁	14.9 ± 0.17	20.5 ± 0.16	661 ± 9.44
T ₂	14.8 ± 0.20	20.7 ± 0.25	658 ± 7.92
T ₃	15.7 ± 0.14	20.3 ± 0.16	659 ± 9.31
T ₄	18.6 ± 0.43	24.8 ± 0.39	788 ± 8.24
T ₅	15.7 ± 0.21	21.4 ± 0.37	651 ± 13.3
T ₆	15.3 ± 0.33	21.6 ± 0.48	660 ± 9.67
T ₇	16.9 ± 0.02	22.1 ± 0.17	703 ± 12.1
T ₈	15.1 ± 0.02	21.4 ± 0.23	654 ± 5.47
T ₉	17.8 ± 0.17	23.2 ± 0.31	746 ± 1.17
T ₁₀	15.4 ± 0.18	21.7 ± 0.47	656 ± 4.80
T ₁₁	15.6 ± 0.19	21.3 ± 0.18	649 ± 2.04
T ₁₂	11.2 ± 0.15	19.2 ± 0.25	607 ± 12.7
SEd	0.27	0.43	16.72
CD	0.57	0.90	33.7

Among the treatments, T₄ (GGKF2) recorded maximum number of nodules (18.6 and 24.8 at 30 and 45 DAS respectively) and this was followed by T₉ (CKB1) which recorded 17.8 and 23.2 nodules at 30 and 45 DAS respectively. However, the lowest number of nodules (11.2 and 19.2) was recorded in T₁₂ (control). PPFM had a significant influence on the yield of blackgram. Among the isolates, T₄ (GGKF2) recorded the highest yield of 788 kg/ha compared to other isolates tested.

DISCUSSION

Isolation of Pink Pigmented Facultative Methylobacteria (PPFM)

In the present study, 49 isolates of methylobacteria were isolated from phylloplane of blackgram, greengram, redgram and cowpea through enrichment isolation of leaf imprinting technique and dilution method in Ammonium Mineral Salts medium. The isolated methylobacterial bacteria could grow on AMS medium supplemented with 0.5 % methanol and 0.1 % filter sterilized Cyclohexamide. Similarly, several researchers have isolated the methylobacteria from phylloplane of rice, sugarcane, groundnut, cotton, field bean, blue pea, cowpea, mungbean, soybean, blackgram, sirato, chickpea, hyacinth bean, garden pea, sunhemp, sesbania, daincha and tropical legumes (Madhaiyan *et al.*, 2004; Jourand *et al.*, 2004; Madhaiyan *et al.*, 2005; Madhaiyan *et al.*, 2006a,b; Madhaiyan *et al.*, 2009a; Holland, 2011).

Morphological Characterization

All the 49 isolates were observed for their morphological characters such as colony colour, form, elevation and margin. Most of the colonies were pink, pale pink or dark pink in colour due to pigmentation and they were mostly circular, flat and regular. Similarly, several researchers have reported the colonial morphology of the isolates in AMS which were similar in terms of shape, margin, elevation and optical density. They possessed round, raised, smooth margined and translucent colonies. The variations were observed in terms of intensity of pigmentation, size and consistency of the colonies (Carvajal *et al.*, 2006 ; Lo and Lee, 2007; Jang and Lee 2008).

There was significant increase in the plant growth parameters like shoot length, root length, nodule number and yield. In this present study among different treatments, the isolate T₄ (GGKF2) recorded the higher shoot and root lengths.

Basile *et al.* (1969) first demonstrated the growth enhancing effects of PPFMs on plants. In a tissue culture system, they demonstrated that PPFMs produce a diffusible substance that stimulates the growth of *Scapania nemerosa*, a liverwort with which the bacterium is regularly associated. The number of nodules were maximum in the treatment T₄ (GGKF2) followed by the treatment T₉ (CKB1) at 30 and 45 DAS and was significantly superior over the control in both pot culture and field experiments. The increase in the nodule

number influencing the legume roots to secrete growth promoting substances, which in turn might have enhanced the growth of *Methylobacterium in situ* and a synergistic effect may have achieved in case of treatment T4 and T9. This results have shown conformity with the results of Dorosinsky and Kayrov, (1975) who worked on chickpea and observed that inoculation of chickpea with *Rhizobium* increased the nodulation, nitrogen fixation and yield of crop. Whereas at 60 DAS, there was gradual decrease in all nodule parameters, the nodule formation reaches its peak during flowering stage and senescence of nodules occur as the plant matures. It is mainly due to reduced biosynthesis of leghaemoglobin in nodule as plant matures. Similarly, Schiffmann and Label (1973) reported that nodule senescence occurred as the plant matured because of decreased biosynthesis of leghaemoglobin in peanut nodules. The maximum nodule number of due to inoculation of two or more beneficial organisms over single inoculation and uninoculated control has been reported (Iruthayathas *et al.*, 1983; Rao and Dhir, 1993; Alagawadi and Guar, 1988; Balachander and Nagarajan, 1999; Singh, 1996 and Sivaprasad and Rai, 1991).

Yield parameters

The yield parameters such as number of pods per plant and grain yield was recorded highest in treatment T4 (GGKF2) followed by treatment T9 (CKB1). In the present study compared to pot culture experiments, the maximum yield was recorded in the field experiment due to the application of inorganic fertilizers. The increases in yield due to PPFM inoculation with PGPR over control have been well reported by (Mehta and Ram Mohan Rao, 1996; Defreitas *et al.*, 1997; Raut and Masood Ali, 1983; Prabhakaran *et al.*, 1999). The increase in the yield due to compatible nature of *Methylobacterium* and *Rhizobium* which was established by Senthilkumar *et al.* (2002). Due to their compatible nature combined influence on phyllosphere by methylotrophs plant growth promoting phyllosphere (PGPP) bacteria and on rhizosphere by *Rhizobium* nitrogen fixing bacterium might have resulted in increased plant growth and yield parameters. This results are similar with the various literatures on the beneficial aspects of pink pigmented *Methylobacterium* sp. as a potent biofertilizer for increasing crop production in soybean (Long, 2000), maize, blackgram, groundnut, sugarcane, rice, cotton, sunhemp (Madhaiyan, 2002), tomato (Anu Rajan, 2003 and Thangamani and Sundaram, 2005c). Similarly Suresh Reddy *et al.* (2002) worked on the

effect of combined inoculation of PPFMs and *Rhizobium* on groundnut variety Co(Gn)4 and observed that there was significantly increase in plant growth, biomass production and yield parameters .

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THE MILLET MAKEOVER: VALUE ADDITION FOR TASTE, NUTRITION, AND CONVENIENCE

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Abstract

Millets are increasingly recognized worldwide for their resilience, nutritional richness, and critical role in ensuring food security and environmental sustainability. Celebrated through the International Year of Millets 2023, these ancient grains have gained renewed attention for their contributions to sustainable agriculture, climate-smart practices, and the fight against hidden hunger. Rich in essential nutrients and bioactive compounds, millets offer numerous health benefits, including the prevention of chronic diseases. However, their broader adoption is hindered by cultural perceptions and limited consumer appeal. Advancements in post-harvest technology and processing methods are addressing these barriers by enhancing the taste, texture, shelf life, and nutritional value of millet-based products. This article explores the importance of processing and value addition in millets, reviewing technologies that support the development of diverse, convenient, and health-oriented products, including gluten-free and fortified options. Supported by policy initiatives and increased public awareness, ongoing efforts aim to reposition millets as modern, accessible, and desirable foods for both niche and mainstream markets.

Keywords: Processing, Fermentation, Value Addition, Malting

Introduction

In India, millets hold deep cultural and historical significance and are referred to as “Shree Anna,” meaning the best among all food grains. As of the 2023–24 agricultural year, millets were cultivated over approximately 12.19 million hectares, with an estimated production of 15.38 million tonnes, contributing around 10% to India's total food grain basket (APEDA, 2024). These crops are also known as “Nutri cereals” due to their high nutritive value, encompassing both major and minor nutrients such as carbohydrates, fats, proteins, vitamins, minerals, antioxidants, and phytochemicals (Singh et al., 2020). Due to their nutrient density, millets play a role in managing various health conditions such as diabetes, migraine, asthma, atherosclerosis, hypertension, and heart disease (Birania et al., 2020). Despite their exceptional nutritional profile, millets remain underutilized. To improve their adoption and consumption, advancements in processing technologies are necessary to enhance sensory attributes, nutritional quality, and ease of use (Rathore et al., 2016). Moreover, millets are particularly rich in polyphenols, flavonoids, and antioxidants, which significantly contribute to their nutraceutical potential and health-promoting properties (Babypriyanka et al., 2025). This article delves into the stages of millet processing and value addition, emphasizing ready-to-eat (RTE) products that can attract modern consumers to these nutrient-rich grains.

Technologies for Processing of Millets

Processing of millets is a crucial task as it involves removal of the inedible portion and converting them into cooked and edible part thereby increasing the physiological and chemical accessibility of micronutrients and also decreases antinutrients (Hotz & Gibson.,2007). Processing technology of millets involve two methods namely Primary processing and Secondary processing. Primary processing methods involves dehulling, milling, malting and fermentation, whereas Secondary processing involves the processing of primarily processed raw material to ready-to-cook and ready-to-eat products by implementing techniques such as flaking, extrusion, popping, baking, and producing final products like flakes, pasta, vermicelli, pops, biscuits, multigrain flour and multigrain roti/dosa etc (Dayakar Rao *et al.*,2017). Due to the absence of specialized processing machineries for processing of millets, these are usually processed in rice and wheat processing machineries in which the grain recovery is very low ranging from 63% to 79%, with 16% to 29% husk and 5% to 9% bran (Sarojani *et al.*, 2020).

1. Dehulling

Dehulling plays a major role in enhancing the palatability of millets, which cannot be consumed in its natural state or in processed forms like flour and other food products. This process is challenging because of their smaller grain size and it also results in nutrient loss (Amadou *et al.*, 2013). To address this challenge, decortication is carried out only to a limited extent, removing only 12-30% of the outer surface of the grain (Rathore *et al.*, 2016). An improved dehulling technology is required for more efficiency, which ensures selective removal of only the outer surface without causing any unnecessary loss of grains. The introduction of a double-chamber centrifugal dehuller, as an innovative solution, has significantly helped in the increased recovery of unpolished dehulled grains (Durairaj *et al.*, 2019). The consumption of dehulled millets has been associated with a protective effect against the development of cardiovascular disorders, type 2 diabetes, and pancreatic cancer (Senthamil & Tamilmounika., 2022.).

2. Milling

Milling process typically involves hammer or roll mills and the flour produced from such mills have larger particle without uniformity and are not suitable for preparing thin porridge as well as for making smooth textured steamed or baked foods. This process plays a major role in lowering the phytic acid and polyphenol levels simultaneously enhancing the digestibility of starch and protein (Chowdhury & Punia., 1997).

3. Malting

Malting has been practiced as a traditional processing technique in certain parts of India (Chandrasekhara & Swaminathan., 1953). This process helps in reducing the phytate levels in grains and enhancing the iron and zinc availability (Sarojani *et al.*, 2020). Malting involves three major processes namely steeping, germination and drying (Capanzana & Buckle., 1997). Steeping involves immersing the millet grains in water until they are imbibed with sufficient amount of water to start the germination process along with simultaneous removal of dirt, chaff and broken kernels through washing and floatation, which is followed by germination that takes about 2-6 days with an optimum temperature of 25°C to 28°C. Drying, which is the final process wherein the germinated kernel grains are dried at a temperature of 20°C for about 24 hrs, which reduces the moisture content thereby terminating the further growth of the kernels (Baranwal., 2017). The germinated rootlets are removed after drying, and the grains are used for the

preparation of weaning food and other milk-based formulations. Malted grains are commonly utilized in manufacturing weaning foods for young children (Malleshi., 1989).

4. Fermentation

Fermentation is a primary processing technique for millets, carried out under anaerobic conditions to inhibit the growth of undesirable microorganisms while encouraging the proliferation of beneficial microbes. This biological process facilitates the breakdown of complex macromolecules, thereby enhancing the bioavailability of nutrients and significantly reducing antinutritional factors such as phytic acid and tannins (Rathore et al., 2016). Prolonged fermentation improves amylase activity and increases soluble sugar content, contributing to better digestibility. Moreover, fermentation enhances the synthesis of B-complex vitamins, boosts antioxidant properties, and introduces probiotic elements that support gut health and immunity (Elkhalifa et al., 2005; Sharma et al., 2022). Traditionally, fermentation is used to prepare culturally significant beverages like *bajra ki raab* and *ragi malt*. In recent years, contemporary innovations have focused on developing probiotic-rich millet-based drinks tailored for health-conscious consumers.

Value Addition and Value-added products in Millets

Although millets are nutritionally superior to many staple grains, they face social and cultural barriers that hinder their widespread adoption. In some regions, millets are perceived as a "poor man's crop" or a food associated with famine, making them less desirable compared to rice and wheat (Moho et al., 2023). However, value addition can enhance their appeal, particularly among urban consumers.

1. Multigrain Flour

Despite their rich nutrient profile, millets are not widely utilized. One way to increase their consumption is by blending them with wheat flour after suitable processing (Singh A et al., 2020). Multigrain or composite flour combines different millet varieties to create a more wholesome flour. For example, chapatis made with a mixture of wheat and finger millet not only improve taste but also help regulate blood sugar levels, benefiting diabetic patients (Ravinder et al., 2008). Researchers examined composite flours created by mixing foxtail, barnyard, and finger millet with wheat flour in varying proportions (10-30%). The study revealed that adding millet flour increased protein, fat, and ash content while reducing carbohydrates (Singh et al., 2020).

2. Puffing/Popping

Puffing or popping is a traditional method of processing millets, commonly used in breakfast cereals. This technique alters the starch or starch-protein structure of millet grains, causing them to expand and develop a crisp texture (Saraswathi & Hameed, 2022). Research on finger millet puffing showed a 9.3% reduction in neutral lipids, while glycolipids increased by 21.92% and phospholipids by 33.3% (Wadikar *et al.*, 2007). Value-added products such as nutrient bars can be created using popped grains like sorghum, ragi, and pearl millet, along with dry-roasted nuts. Additionally, popped sorghum can be used to make chocolate-coated millet snacks.

3. Fermented Foods

Fermentation has long been used to enhance flavours and improve the nutritional profile of foods by increasing probiotic content. Popular fermented foods such as dosa and idly are staple meals in South India. A blend of millets and black gram (*Vigna mungo*) in a 3:1 ratio, which is wet ground, fermented overnight, and then steamed to prepare idly or cooked on a pan to make dosa has its own preference (Malleshi, 1989). The combination of germination and probiotic fermentation improves the levels of essential nutrients, including thiamine, niacin, lysine, protein fractions, soluble dietary fibre, and minerals such as calcium, iron, and zinc (Arora *et al.*, 2011). Traditional millet-based fermented drinks like "bajra ki raab" and "ragi malt" hold cultural significance in various regions and are valued for their health benefits.

4. Bakery Products

Adding millets to bakery products enhances fibre content and micronutrients, making them a viable alternative in the baking industry (Verma & Patel, 2013). Studies suggest that millet flour can replace up to 20% of wheat flour in baked goods without compromising texture or nutritional value (Awadalla & Slump, 1974). However, higher millet content can alter the texture of baked goods. Researchers experimenting with 100% sorghum or pearl millet in cookies found that the texture of the product was tough, gritty, and lacked the desirable surface cracks and spread (Eneche, 1999). Millet biscuits have also been developed by blending millet flour with pigeon pea flour in various ratios (Eneche, 1999).

5. Extruded Products

Extrusion cooking is an effective method for processing millets into ready-to-eat (RTE) products. This high-temperature, short-time (HTST) technique fully gelatinizes and cooks food,

making it ideal for both starchy and protein-rich materials. Extrusion offers benefits such as versatility, high production efficiency, improved product quality, enhanced protein digestibility, and minimal waste generation (Dahlin & Lorenz, 1992). Some of the value-added product made from extruded millet grains includes,

- i. **Millet Puffs:** These are light, crunchy snacks made by extruding millet grains. They come in various flavours, from classic salted to spicy and tangy options.
- ii. **Millet Cereals:** Extruded millet cereals are a quick and nutritious breakfast option. They often come in different shapes and are fortified with vitamins and minerals.
- iii. **Millet Bars:** Healthy snack bars can be made by extruding millet grains and binding them together with natural sweeteners like honey. These bars are convenient for on-the-go snacking.
- iv. **Millet Pasta:** Extruded millet pasta provides a gluten-free alternative to traditional wheat-based pasta. It retains a pleasant texture and pairs well with various sauces.
- v. **Millet Snack Mix:** A mix of extruded millet shapes, combined with nuts, seeds, and dried fruits, creates a wholesome and flavourful snack mix.
- vi. **Millet Extruded Flour:** This specialized flour is produced by extruding millet grains and can be used as a base for gluten-free baking, making it suitable for those with gluten sensitivities.

6. Malting and Weaning Foods

Millet malt has traditionally been used for infant nutrition due to its rich nutritional profile. The malting process enhances the grain's nutrient composition, increasing fibre, crude fat, and essential vitamins such as B and C, while also improving mineral availability (Sangita & Srivastava, 2000). This process boosts nutrient bioavailability and enhances the taste and texture of the grains. Millet malt is commonly utilized as a base ingredient in weaning foods, dietary supplements, health foods, and amylase-rich formulations due to its low dietary bulk and high-calorie density. Germination is a crucial step in malting that must be carefully managed, with an optimal temperature generally exceeding 22°C (Saraswati & Hameed, 2022).

7. Sprouted millet milk beverage

In research experimented by Geetha and Kanchana, Sprouted kodo millet is added with water in the ratio of 1:7 and milk was extracted. The extracted milk contained 1.2% protein, 5.73% starch, 1.79% reducing sugar, 3.26% Total sugar, 1.21% protein, 1.63% calcium and 0.86

acidity. The extracted samples also found to have a shelf life of three months in refrigerated conditions (Geetha & Kanchana., 2022).

8. Millet Microgreens

Sprouts, Microgreens and Baby leaf vegetables has been focused increasingly because of their various health benefits to humans (Di Gioia *et al.*, 2017.). Millet microgreens especially sprouting of pearl millets grains show increased production of phenolics and antioxidant activity (Sharma & Gupta., 2021.).

9. Millet Ice-cream

The millet-based ice creams were found to have an appreciable amount of carbohydrate, protein, fat, calcium and phosphorus. This Non-dairy ice cream formulated with barnyard millet, soyabean and coconut extract has shown better acceptability and can be also consumed by people with lactose intolerance, milk protein allergy and vegans (Amritha *et al.*, 2021).

Conclusion

Processing and value addition of millets emerge as integral components in the pursuit of a sustainable and nutritious food landscape. The diverse processing techniques showcased in this review not only enhance the accessibility of millet-based products but also contribute to the preservation of their inherent nutritional benefits. As we navigate the challenges of a rapidly changing global food system, investing in millet processing and value addition becomes not just an option but a necessity. By recognizing the potential of these humble grains, it is necessary to pave the way for a future where millets play a pivotal role in addressing both nutritional needs and environmental sustainability. The journey towards a healthier world starts with the transformative power of millet processing and value addition.

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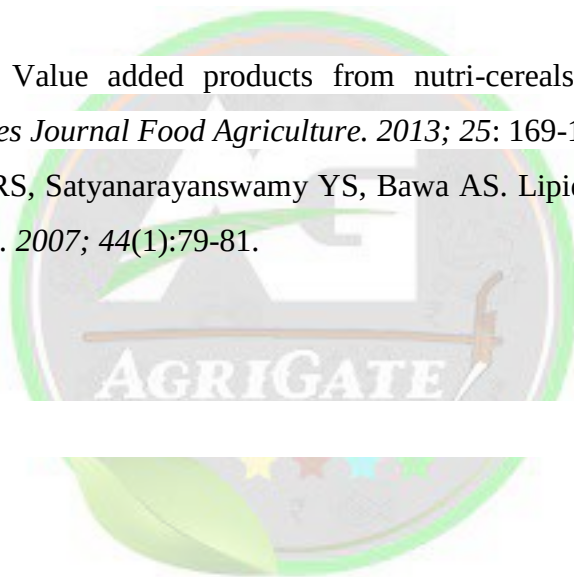
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NANO UREA: CURRENT PERSPECTIVE IN AGRICULTURE

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Abstract

Nano urea, a novel nano-fertilizer formulated using nanotechnology, has emerged as a promising solution to enhance nitrogen use efficiency (NUE) while minimizing environmental degradation associated with conventional urea use. This paper reviews the current adoption, efficacy, challenges, and future prospects of nano urea in agriculture, with a particular focus on its role in sustainable nutrient management. While early results suggest improvements in yield and reductions in nitrogen losses, challenges related to field efficacy, farmer awareness, and regulatory oversight persist.

Introduction

Nitrogen is deficient in most of the Indian soils particularly in the light textured ones, which is one of the basic plant nutrients. Nitrogen is involved in the formation of proteins, nucleic acids, growth hormones, vitamins and also an integral part of chlorophyll. Urea is widely used nitrogenous fertilizer in the country because of its high N content (46% N) as well as cheapest source of N. Nitrogen is a critical nutrient in crop production, but the low efficiency of conventional urea (30–40% uptake) has led to significant losses to the environment via leaching, volatilization, and denitrification. The development of nano-scale fertilizers, particularly nano urea, has been proposed as an innovative method to address these inefficiencies. India, through the Indian Farmers Fertiliser Cooperative Limited (IFFCO), has been at the forefront of deploying nano urea at scale (IFFCO, 2022).

Composition and Mechanism of Action

Nano urea is a liquid formulation containing nitrogen particles at the nanoscale (<100 nm). When applied as a foliar spray, these particles are rapidly absorbed through leaf stomata

and cuticles, offering a more targeted and efficient nitrogen delivery mechanism. A 500 mL bottle of nano urea is reported to replace a 45 kg bag of conventional urea under recommended usage (IFFCO, 2022).

The science behind Nano Urea

In the Nano Urea (Liquid), 4 per cent nanoscale nitrogen particles are present. Nanoscale nitrogen particles are smaller (30-50 nm) and have greater surface area and particles per unit area than traditional urea. Because nano urea solutions can easily penetrate the plant's cell wall, they result in more effective nitrogen absorption, higher physiological growth and grain production when sprayed via foliar (Kumar *et al.*, 2024).

Current Adoption and Policy Support

The Government of India has aggressively promoted nano urea through subsidy schemes, demonstrations, and integration into national soil health and fertilizer-use efficiency programs. Field trials in major crops such as rice, wheat, maize, and sugarcane have shown varied but generally positive outcomes (Singh and Meena, 2023). Globally, nano urea remains in experimental or pilot phases in most countries.

Research and Promotion in India (with a focus on IFFCO):

India has been at the forefront of Nano Urea development, primarily driven by IFFCO.

Development and Approval: IFFCO Nano Urea (Liquid) is the world's first nano-fertilizer to be notified by the Fertilizer Control Order (FCO, 1985), Government of India, following extensive bio-efficacy and toxicology assessments.

Manufacturing and Availability: Several Nano Urea plants have been set up in India by IFFCO and other PSUs (like NFL, RCF) to meet the demand. It is made available through various channels, including Pradhan Mantri Kisan Samridhi Kendras (PMKSKs).

Promotion and Awareness: The Government of India and fertilizer companies actively promote Nano Urea through various activities such as awareness camps, webinars, field demonstrations, Kisan Sammelans, and the "Namo Drone Didi" scheme, which provides drones to women Self Help Groups for efficient application of nano fertilizers (FAO, 2021).

Agronomic Performance

Recent Studies indicate:

- Improved NUE By 15–30%
- Increased yields by 5–10% when used as a supplementary Foliar Spray

- Reduced requirement for basal nitrogen application

However, performance is contingent on:

- Crop Type and growth stage
- Environmental conditions
- Integration with existing nutrient regimes

Environmental and Economic Impacts

Nano urea has the potential to:

- Reduce nitrogen runoff and greenhouse gas emissions
- Decrease dependence on bulk urea production and imports
- Improve farm economics by reducing fertilizer input costs.

These benefits align with climate-resilient and sustainable agriculture frameworks endorsed by international organizations such as FAO and UNEP.

Challenges and Limitations

Despite its promise, nano urea is not without challenges:

- Inconsistent field efficacy across geographies and crops.
- Lack of farmer training on appropriate application methods.
- Regulatory and safety concerns, especially regarding long-term soil health and nanoparticle accumulation.

Overreliance may lead to under-fertilization if not integrated properly with conventional nutrients

Future Outlook

Continued research is essential in the following areas:

- Crop-specific formulations
- Nano urea's interaction with soil microbiota
- Integration with precision agriculture tools (e.g., drones, sensors)
- Development of regulatory standards for nano fertilizers
- Interdisciplinary collaboration among agronomists, soil scientists, and policymakers will be key to optimizing nano urea's role in future nutrient management strategies.



Conclusion

Nano urea presents a significant innovation in sustainable agriculture, with the potential to enhance nitrogen efficiency, reduce environmental pollution, and support national food security goals. However, its success depends on informed usage, regulatory support, and continued empirical validation across diverse agricultural systems.

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REVIEW ON WEATHER FORECASTING BY METEROLOGICAL DATA

Article ID: AG-VO5-I05-115**Elangovan P¹, Venujeyakanth B ² and Mahalingam A^{1*}**¹Regional Research station, Vridhachalam, TNAU, Tamil Nadu, India²S. Thangapazham Agricultural College, Tenkasi, Tamil Nadu, India

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Introduction

Weather forecasting has undergone a profound transformation, moving from traditional observation-based methods to highly sophisticated, data-driven approaches. The increasing availability of vast amounts of weather data, coupled with advancements in computational power and artificial intelligence (AI), has revolutionized the accuracy and scope of weather predictions (Varshney and Ram, 2024). Here's a review of key aspects of weather forecasting using weather data:

I. The Evolution of Weather Forecasting

Traditionally, weather forecasting relied on:

- **Empirical observations:** Meteorologists would analyze current weather conditions, barometric pressure changes, and sky conditions to make predictions.
- **Synoptic method:** This involved studying weather maps to track the movement and intensification of weather systems.
- **Numerical Weather Prediction (NWP):** This marked a significant leap, using physics equations (fluid dynamics, thermodynamics) to simulate atmospheric behaviour. NWP models process observational data from weather stations, balloons, and satellites using supercomputers (Wu and Xue, 2024).

II. The Role of Weather Data

Accurate weather data is the bedrock of effective forecasting. A wide array of data sources contributes to this:

- **Surface Observations:** Data from automated weather stations on land and weather buoys at sea provide crucial ground-level information (temperature, humidity, wind speed/direction, pressure).
- **Upper-Air Observations:** Weather balloons released twice daily gather vertical atmospheric profiles, measuring pressure, temperature, and humidity at various altitudes.
- **Satellite Data:** Satellites provide continuous imagery of cloud cover, temperature, and atmospheric pressure, essential for global and regional forecasting. Examples include GOES and MODIS.
- **Radar Data:** Doppler and Dual-Pol radars track precipitation, wind speeds, and intensity, crucial for short-term forecasts and detecting severe weather events like tornadoes.
- **Oceanic Data:** Argo Floats measure temperature and salinity at various ocean depths, while Sea Surface Temperature (SST) satellites monitor ocean temperatures, influencing atmospheric patterns.
- **Crowdsourced Data:** With the proliferation of personal weather stations and smartphone apps, crowdsourced weather data contributes to localized, real-time monitoring.
- **Historical Records (Reanalysis Data):** Decades of historical weather data are crucial for training models, identifying patterns, and understanding cause-and-effect relationships in atmospheric evolution (Zhang et al., 2025 and Thoai et al., 2018).

III. Impact of Weather Data on Forecasting Accuracy

The quality and quantity of weather data directly impact forecast accuracy:

- **Improved Initial Conditions:** Reliable observations from diverse platforms are crucial for establishing precise initial conditions for NWP models, which directly affects the quality of the forecast.
- **Enhanced Resolution and Detail:** More data allows for higher-resolution weather models, enabling highly detailed and localized forecasts.
- **Better Understanding of Complex Systems:** Comprehensive datasets help meteorologists understand and predict complex weather phenomena, from tropical cyclones to extreme temperatures.
- **Reduced Forecast Errors:** Continuous advancements in data assimilation techniques, which integrate observations into model representations, have significantly reduced forecast errors.

- **Longer Lead Times:** Increased data and improved models have extended the lead time for accurate deterministic forecasts (e.g., out to 10 days) and probabilistic predictions (monthly to seasonal).

IV. Advancements Through Big Data and AI/Machine Learning

The sheer volume, velocity, and variety of modern weather data fall under the umbrella of "Big Data," leading to significant advancements:

- **Big Data Analytics:** Analyzing these massive datasets helps extract concealed patterns and valuable information, improving forecasting precision.
- **Machine Learning (ML) and Deep Learning (DL):** These techniques have revolutionized weather forecasting by:
 - **Pattern Recognition:** ML algorithms can identify complex patterns in vast datasets (satellite imagery, atmospheric data) that are difficult for traditional methods to detect.
 - **Enhanced Short-Term Predictions:** Especially for rapidly changing conditions, ML models excel at short-term forecasts.
 - **Bias Correction:** AI can identify and correct biases in numerical models, further improving accuracy.
 - **Hyper-Local Forecasting:** AI-powered tools can generate highly localized predictions by considering local geography, infrastructure, and urban effects.
 - **Faster Processing:** ML models can perform forecasts much more efficiently and at lower computational cost compared to traditional supercomputer-intensive NWP. Notable examples include Google DeepMind's GraphCast and Huawei's Pangu-Weather.
 - **Data Assimilation Improvement:** ML can be used to better estimate components of NWP and model error in the data assimilation process.
 - **Ensemble Prediction Systems:** ML can contribute to developing ensemble systems that generate multiple slightly different forecasts to assess uncertainty.
- **Cloud Computing:** Provides scalable platforms for processing and analyzing large amounts of weather data efficiently.

- **Visualization Tools:** Advanced visualization tools, including 3D visualizations and interactive maps, help meteorologists interpret and communicate complex weather data effectively (Olivetti and Messori, 2024).
- **IoT Integration:** Real-time data from IoT devices like weather sensors and drones provide localized atmospheric conditions.

V. Challenges and Future Directions

Despite significant progress, challenges remain:

- **Chaotic Nature of the Atmosphere:** The inherent chaotic nature of the atmosphere means that forecasts inherently become less accurate over longer lead times.
- **Computational Demands:** While AI offers efficiency, training complex AI models still requires substantial computational resources.
- **Data Quality and Gaps:** Ensuring the quality, consistency, and completeness of diverse data sources is critical.
- **Climate Change Impacts:** Increasing frequency and intensity of extreme weather events, and more rapid development of phenomena like hurricanes due to warming climates, can reduce predictability.
- **Interpretable AI:** Making AI models "interpretable" is crucial to understand *why* they make certain predictions, enhancing trust and enabling further model improvements.
- **Integration of Physics-Based and Data-Driven Models:** The future likely involves a hybrid approach, where ML boosts traditional physics-based models rather than completely replacing them.
- **Quantum Computing:** Emerging technologies like quantum computing hold the potential to process atmospheric data at unprecedented speeds for real-time, hyper-accurate forecasts.
- **Global Data Sharing:** Enhanced global data-sharing networks are crucial for collaborative advancements in weather forecasting (Bouallègue et al., 2024).

Conclusion

Weather forecasting has been profoundly transformed by the increasing volume and diversity of weather data, coupled with the power of Big Data analytics and artificial intelligence. These advancements have led to more accurate, timely, and localized predictions, benefiting various sectors from agriculture and transportation to disaster preparedness and daily

life. The continuous integration of new data sources and the ongoing development of sophisticated AI and computational techniques promise even greater precision and resilience in the face of dynamic weather patterns.

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KNOLKHOL (*BRASSICA OLERACEA* L. VAR. *GONGYLODES*): ORIGIN, CULTIVATION PRACTICES, AND YIELD POTENTIAL

Article ID: AG-VO5-I05-116**M. Karal Marks¹ and Dr.K. Sundharaiya²**

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Introduction

The knolkhol or kohlrabi, *Brassica oleracea* L. var. *gongylodes* ($2n=18$), is an important vegetable crop in Europe. It is also grown in the USA, Canada, Japan, and South Korea. In India it is cultivated in northern parts of India (Kashmir, Himachal Pradesh, Punjab, Uttar Pradesh, West Bengal, Assam), and in some areas of southern States (Karnataka, Tamil Nadu), and Maharashtra. It is not grown on a large scale in the country. Knolkhol is fried or cooked in curries and sambhar.

Origin and domestigation:

Knolkhol had evolved from a marrow-stem non-heading type of kale, perhaps varcostata, the Portuguese kale or the varmedullosa in the middle of the Mediterranean area. It was first described in Europe in 1485.



It was first grown in Ireland in 1724 and in England in 1837. It may have come from southern Europe, perhaps Italy, as indicated by the names of the two most popular varieties, White Vienna and Purple Vienna.

Genetics

Knolkhol is a biennial and cross-pollinating crop with self-incompatibility. It produces seeds in the hills. It does not have much genetic diversity. Its edible swollen stem, known as knob, is round with leaves over it. The colour of knob may be green/white and purple in different varieties. Self-incompatibility is sporophytic monogenic multiple allelic system with dominance relationship as in cabbage and cauliflower.

Knolkhol has cytoplasmic male sterility (CMS) with sterile Ogura cytoplasm from radish similar to CMS in cabbage, cauliflower and broccoli. Hybrids are developed by using CMS system. Earlier varieties were evolved by selection and now several F_1 hybrids have been developed in the USA and some other countries, like Japan.

Varieties

Variety	Chief characteristics
White Vienna	Early, dwarf stems and leaves medium green, knobs globular to flat round, light green, creamy white flesh, maturity 50-60 days after transplanting
King of North	Plant height 20-30 cm, foliage broad, dark green, knobs flat round, leaf sheath large, maturity 60-65 days.
Large Green	Late variety (75 days), leaves broad, dark green, knobs flat round, dark green, recommended for mid-and high hills of Himachal Pradesh and western Himalayas.
Purple Vienna	Early, dwarf, leaves purple, knobs globular, purplish, flesh greenish white, maturity 55-65 days.



White vienna



Purple vienna

Climate

Temperature: It thrives in cool climates, with an ideal temperature range of 10°C to 20°C.

Frost Sensitivity: KnolKhol is sensitive to frost, so it should not be exposed to freezing temperatures.

Rainfall: Requires consistent rainfall or irrigation for steady growth but should not be waterlogged.

Humidity: Moderate humidity levels are ideal; excessive moisture can cause fungal diseases.

Sunlight: It prefers full sunlight but can tolerate partial shade.

Soil

It can be grown on a wide range of soil. However, light loam rich in organic matter and well-drained is the most suitable soil for its growing. It is slightly tolerant to acidic soil. optimum soil pH is 5.5-6.8.

Sowing and Transplanting:

Seeds are sown in nursery beds to produce seedlings. After about 30-45 days of sowing, the seedlings are ready for transplanting in the field. The plants are spaced 25cm – 25cm or 30cm -30cm. The seed rate is about 1-1.5 kg per hectare.

In northern plains seeds can be sown in September – October or during late August to November depending on the location. Seeds are sown in March – April in the hills. In Karnataka and neighbouring areas of Tamil Nadu seeds are sown in September – October and June – July.

Manures and Fertilizers:

About 25-30 tonnes per hectare of FYM and fertilizes 100 kg N, 60 kg P and 40-60 kg K per hectare are applied to the soil at ploughing and field preparation. Half quantity of N is used for basal application along with P and K and the main half quantity of N is topdressed after 30-35 days of transplanting of seedlings.

Irrigation

Water Needs: It requires consistent moisture throughout its growth cycle.

Irrigation Frequency: Watering should be regular, especially during dry spells, but overwatering should be avoided.

Soil Moisture: The soil should be kept moist but not soggy; moderate soil moisture is ideal.

Early Growth: During the early growth stages, more frequent watering is needed to support seedling establishment.

Mature Plants: Once the plants mature, the frequency of irrigation can be reduced.

Drip Irrigation: Drip irrigation is recommended to avoid waterlogging and fungal diseases.

Intercultural operation:

Weeding: Regular weeding is important to prevent competition for nutrients and water.

Mulching: Apply mulch to retain soil moisture, control weeds, and regulate soil temperature.

Thinning: Thin seedlings to allow adequate space for healthy bulb development.

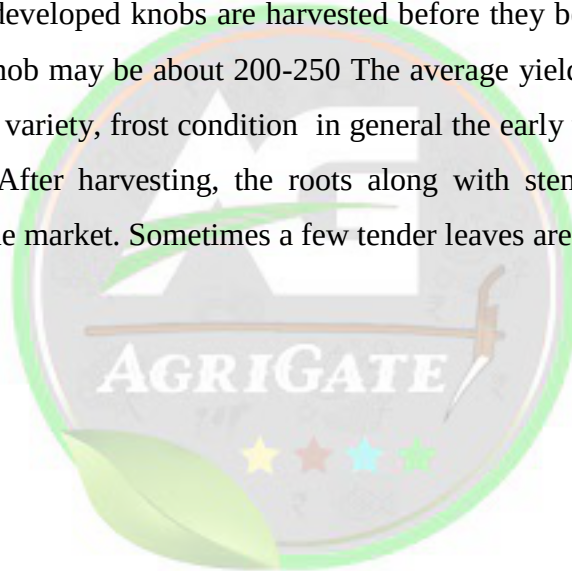
Hoeing: Regular hoeing loosens the soil and improves aeration for better root growth.

Earthing Up: Soil should be heaped around the base of the plants to support the growth of bulbs.

Pruning: Remove any dead or yellowing leaves to improve airflow and reduce disease risks.

Harvesting and Yield:

The tender fully developed knobs are harvested before they become fibrous from inside. The average weight of knob may be about 200-250 The average yield is about 12-30 tonnes per hectare depending on the variety, frost condition in general the early varieties yield less than the late maturing varieties. After harvesting, the roots along with stem and leaves are removed before these are sent to the market. Sometimes a few tender leaves are left on the knob.



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ARROWROOT (*MARANTA ARUNDINACEA*): A VERSATILE CROP FOR NUTRITION, INDUSTRY, AND SUSTAINABLE CULTIVATION

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Introduction

Arrowroot (*Maranta arundinacea*) is a tropical plant widely cultivated for its starchy rhizomes. These rhizomes are the primary source of arrowroot starch, which is extracted and used in various industries, including food, pharmaceuticals, cosmetics, and textiles. Arrowroot starch is renowned for its high digestibility, hypoallergenic properties, and versatility as a thickening agent. It is often used as an ingredient in gluten-free, baby foods, and health-conscious diets due to its ease of digestion and ability to blend well in cooking.

Arrowroot is also known for its role in sustainable agriculture, especially in developing countries. It can be cultivated in various soil conditions and can be cultivated with minimal input, making it a popular choice for small-scale farmers in tropical and subtropical regions. The plant's fibrous roots and its ability to thrive in a range of soil types contributes to its sustainability.

Taxonomical Classification of Arrow Root

Kingdom: Plantae

Division: Angiosperms

Class: Monocots

Order: Zingiberales



Family: Marantaceae

Genus: Maranta

Species: Maranta arundinacea

Nutritional Value:

Nutrition	Content
Water	12.1 %
Calories	346
Protein	0.18 g
Fat	0.05 g
Carbohydrate	85.74 g
Ash	1.89 g
Calcium	58.0 mg
Phosphorus	7.2 mg
Iron	0.55 mg

Economic Importance of Arrowroot

- **Food Industry:** Arrowroot starch is a key ingredient in the food industry, particularly for its use as a thickening agent in soups, sauces, puddings, and gravies. It is also a crucial component of gluten-free baking products, baby foods, and low-fat diets due to its light texture and easy digestibility. The food industry is the largest consumer of arrowroot starch, driven by increasing consumer demand for gluten-free and allergen-free options.
- **Pharmaceuticals:** Arrowroot starch is used as a binder and stabilizer in the pharmaceutical industry, particularly in the production of tablets. It helps to give shape to the tablets and ensures the active ingredients are effectively delivered in the body.
- **Cosmetics and Personal Care:** Arrowroot starch is commonly used in cosmetic formulations, such as powders, lotions, and deodorants. It acts as a thickening agent, providing a smooth texture and helping to absorb moisture, which is beneficial in various skin-care products.

Botany of Arrow root

Plant description

Roots and Rhizomes: Arrowroot has fleshy, underground rhizomes that are the primary

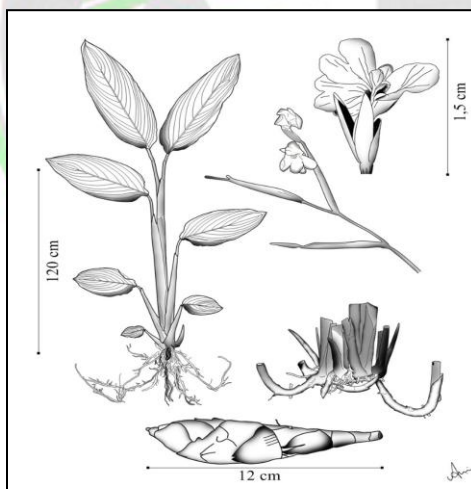
edible part of the plant. These rhizomes store starch and are typically harvested for their starch content. The rhizomes are cylindrical, whitish or creamy in color, and grow horizontally beneath the soil surface.

Leaves: The leaves are large, lance-shaped, and alternately arranged on the stem. They are broad, ovate, and typically have smooth or slightly wavy margins. The leaves are green and may have noticeable veins. The plant can also produce long petioles (leaf stems), contributing to its bushy appearance.

Stem: Arrowroot has an upright, fleshy stem that emerges from the rhizomes. The stem is smooth and non-woody with a simple structure. It does not have a prominent bark and is herbaceous.

Flowers: Arrowroot produces small, spike-like inflorescences that appear at the top of the plant. These flowers are typically white to purple and are relatively inconspicuous. They have a typical structure for a member of the Marantaceae family, with a distinct 3-lobed perianth.

Fruit: The plant produces small, triangular capsules containing small, black seeds.



Temperature Requirements

Arrowroot grows best in temperatures ranging from **25°C to 30°C (77°F to 86°F)**. It is highly sensitive to frost, and temperatures below 10°C (50°F) can damage the plant. Therefore, it is best suited for tropical and subtropical regions.

Arrowroot prefers high humidity levels, typically **60% to 85%**. This is important for the plant's overall health, as it aids in the plant's ability to transpire and grow efficiently. Arrowroot grows well in areas with **full sunlight** but can tolerate some **partial shade**, particularly during

the hottest part of the day. However, the plant does best when it receives ample sunlight for about **4 to 6 hours daily**.

Soil conditions

Arrowroot prefers **loamy soils** that are rich in organic matter. Loam provides a good balance of sand, silt, and clay, which allows for optimal root development and good water retention without waterlogging. Well-drained soils are critical for arrowroot, as waterlogged conditions can lead to root rot and hinder rhizome growth. Sandy loam or light clay soils with good drainage are ideal for arrowroot cultivation.

Soil pH

Arrowroot thrives in **slightly acidic to neutral soils**, with a pH range of **5.5 to 7.0**. The plant can tolerate slightly alkaline conditions but does not grow well in highly acidic soils.

Propagation

Arrowroot (*Maranta arundinacea*) is primarily propagated through **vegetative means** using rhizomes. This method ensures the crop's genetic traits are preserved and allows for faster establishment compared to seed propagation, which is not commonly used.

Planting

Choose healthy, disease-free rhizomes (the underground stem) for propagation. These rhizomes should be mature, firm, and well-developed, with at least one bud or shoot.

Rhizomes used for propagation should be about **10-15 cm** long (4-6 inches) and have at least one or two growing points or buds. Cut the rhizomes into smaller pieces. Ensure each piece has at least one bud or growing point to ensure successful sprouting. Each piece should be around 5-10 cm in length. Plant the rhizomes 5-10 cm deep into the soil. Ensure they are spaced about 30-45 cm (12-18 inches) apart within rows, with 60 cm (24 inches) between rows. Prior to planting, make sure the field has been properly prepared with well-drained, fertile soil. Arrowroot does best in loamy or sandy-loam soils with good organic content.

Fertilizer requirement

A balanced fertilizer with a ratio of 14-14-14 (N-P-K) is recommended for general fertilization. Apply it every 6-8 weeks, depending on the soil fertility and plant growth. Organic options like compost, well-rotted manure, and bone meal can be applied to boost soil fertility.

Irrigation requirement

Arrowroot requires **moderate to high** levels of moisture throughout its growing period.

While it prefers consistently moist soil, it is important that the soil is **well-drained** to avoid waterlogging and root rot. Generally, this means watering **every 2-3 days** during dry periods or whenever the top few inches of soil dry out. Watering might be reduced to **once every 3-4 days**, depending on the climate and soil conditions.

Weed management

Applying a pre-emergence herbicide such as **glyphosate** (for non-organic practices) can effectively kill weeds before they sprout. These herbicides target young weeds, preventing them from competing with the crops. Apply a thick layer (about 3-4 inches) of organic mulch, such as **straw, leaves, or grass clippings**, around the base of arrowroot plants. Mulch suppresses weed germination by blocking light, retains soil moisture, and provides nutrients as it decomposes.

Harvest and yield

Arrowroot can be harvested 10 months after planting. Yield 25 tons per hectare (t/ha) in open areas.



PRINCIPAL COMPONENT ANALYSIS (PCA) FOR GENETIC DIVERSITY ANALYSIS

Article ID: AG-VO5-I05-118**Elangovan P¹, Tamil Mathi T¹ and Mahalingam A^{1*}**¹Regional Research station, Vridhachalam, TNAU, Tamil Nadu, India

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Introduction

Genetic diversity represents the heritable variation within and between populations of organisms. The success of plant breeding depends on the availability of genetic variation, knowledge about desired traits, and efficient selection strategies that make it possible to exploit existing genetic resource. The pool of genetic variation within an inter-mating population is the basis for selection as well as for plant improvement. Before exploiting a population for trait improvement, it is necessary to understand the magnitude of variability in the population which is fundamental for genetic improvement in all crop species.

To develop segregating population, genetic distance estimates form the basis for selecting parental combinations with sufficient genetic diversity and for classifying germplasm into heterotic groups for hybrid crop breeding. Population Grouping can be based on geographical origin, agro-morphological traits, pedigree information, or molecular marker data (Liakat *et al.*, 2011). Genetic distance estimates for population grouping can be estimated by different methods as it is crucial to understand the usable variability existing in the population panel. One of the approaches is to apply multivariate analysis. population, genetic distance estimates form the basis for selecting parental combinations with sufficient genetic diversity and for classifying germplasm into heterotic groups for hybrid crop breeding. Population Grouping can be based on geographical origin, agro-morphological traits, pedigree information, or molecular marker data⁴. Genetic distance estimates for population grouping can be estimated by different methods as it is crucial to understand the usable variability existing in the population panel. One of the approaches is to apply multivariate analysis.

Statistical method of classification is usually by multivariate methods as it has extensive use in summarizing and describing the inherent variation among crop genotypes. Multivariate statistical tools include Principal Component Analysis (PCA), Cluster analysis and discriminate analysis (Oyelola, 2004) . Principal Component Analysis (PCA) can be used to uncover similarities between variable and classify the cases (genotypes), while cluster analysis on the other hand is concerned with classifying previously unclassified materials⁶ . Principal Component Analysis (PCA) is a multivariate technique that analyzes a data table in which observations are described by several inter-correlated quantitative dependent variables. Its goal is to extract the important information from the table, to represent it as a set of new orthogonal variables called principal components, and to display the pattern of similarity of the observations and of the variables as points in maps. 'Proper values' measure the importance and contribution of each component to total variance, whereas each coefficient of proper vectors indicates the degree of contribution of every original variable with which each principal component is associated. The higher the coefficients, regardless of the direction (positive or negative), the more effective they will be in discriminating between accessions.

Principal Component Analysis (PCA) is a widely used multivariate statistical technique in population genetics and evolutionary biology to study genetic diversity. It's particularly powerful for visualizing patterns of genetic variation within and among populations. Here's a review of how PCA is applied and its significance in genetic diversity studies, along with relevant review articles.

Principal Component Analysis in Genetic Diversity: A Review

Introduction

Principal Component Analysis (PCA) is a dimensionality reduction technique. When applied to genetic data (e.g., SNP data, morphological traits), it transforms a large number of potentially correlated variables into a smaller number of uncorrelated variables called "principal components" (PCs). These PCs capture the maximum variance present in the original dataset. The first principal component (PC1) accounts for the largest proportion of variance, PC2 for the second largest (orthogonal to PC1), and so on (Ahlander et al., 2024).

How PCA is Used to Study Genetic Diversity

In genetic diversity studies, PCA is employed to:

1. **Visualize Population Structure:** This is arguably the most common and impactful application. By plotting individuals in a 2D or 3D space defined by the first few principal components, researchers can visually identify:
 - **Genetic Clusters:** Groups of individuals that are genetically more similar to each other than to individuals in other groups, often representing distinct populations or breeds.
 - **Admixture:** Individuals or populations with intermediate positions on the PCA plot, suggesting a history of gene flow or hybridization between distinct ancestral groups.
 - **Geographic Patterns:** Often, the genetic clusters observed in PCA plots correlate with geographic origin, reflecting isolation by distance or historical migration routes.
 - **Outliers:** Individuals that are genetically distinct from the main clusters, which might indicate errors in sampling, recent mutations, or unique evolutionary histories (Abdi and Williams, 2010).
2. **Quantify Genetic Variation:**
 - The eigenvalues associated with each principal component indicate the amount of variance explained by that component. This helps in determining how many PCs are necessary to capture most of the genetic variation in the dataset.
 - The loadings of the original variables (e.g., specific SNPs or morphological traits) on each PC reveal which genetic markers or traits contribute most to the observed patterns of variation.
3. **Identify Key Traits for Selection/Improvement:** In plant and animal breeding, PCA can pinpoint morphological or yield-contributing traits that explain the most genetic diversity among genotypes. This information is crucial for selecting diverse parents for breeding programs aimed at improving specific characteristics.
4. **Detect Cryptic Relatedness:** PCA can reveal subtle genetic relationships between individuals that might not be apparent through simpler analyses.
5. **Quality Control in Genome-Wide Association Studies (GWAS):** PCA is routinely used in GWAS to identify and adjust for population structure, which can otherwise lead to spurious associations between genetic markers and traits (Bhardwaj et al., 2022).

Data Types for PCA in Genetic Diversity

PCA can be applied to various types of genetic data:

- **SNP Data:** Most commonly, genome-wide SNP (Single Nucleotide Polymorphism) data are used. Each individual is represented by their genotypes at thousands or millions of SNP markers.
- **Microsatellite Data:** While less common now due to the prevalence of SNP arrays and sequencing, microsatellite markers were historically used for PCA.
- **Morphological Traits:** In plant and animal breeding, quantitative morphological traits (e.g., plant height, fruit size, yield components) are often subjected to PCA to understand the overall phenotypic variation and identify key traits contributing to diversity.
- **Gene Expression Data:** PCA can be applied to gene expression profiles to identify clusters of individuals with similar expression patterns, potentially related to environmental adaptation or disease states (Elhaik, 2022 and van Waaij et al., 2023).

Advantages of PCA

- **Simplicity and Interpretability:** PCA provides a straightforward visual representation of complex genetic relationships.
- **Unsupervised Learning:** It does not require prior knowledge of population groups.
- **Dimensionality Reduction:** It effectively reduces high-dimensional genetic data into a manageable number of components, making visualization and interpretation feasible.
- **Robustness:** It is relatively robust to minor errors or missing data (Greenacre et al., 2022).

Limitations and Considerations

While powerful, PCA has some limitations and requires careful interpretation:

- **Sensitivity to Sampling:** Uneven sampling of populations can distort PCA results, making some groups appear more divergent than they truly are.
- **Assumptions:** PCA assumes linearity and that the principal components explain the most important variance. It may not capture complex, non-linear relationships.
- **Interpretation of PCs:** While PCs summarize variance, their biological interpretation is not always straightforward and requires careful consideration of the original variables' loadings.

- **Artifacts and Biases:** Recent research (e.g., Elhaik, 2021) has highlighted that PCA can sometimes produce artifacts and biased results, especially under specific sampling schemes or when interpreting ancient DNA. It's crucial to consider these critiques and potentially use complementary methods (e.g., ADMIXTURE, TreeMix).

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NUTRITIONAL PROFILING AND HEALTH BENEFITS OF SESAME OIL

Article ID: AG-VO5-I05-119**Elangovan P¹, Sathish kumar R² and Mahalingam A^{1*}**¹Regional Research station, TNAU, Vridhachalam, Tamil Nadu, India² Department of Genetics and Plant Breeding, Centre for Plant Breeding and Genetics,
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Introduction

Sesame (*Sesamum indicum* L.) is one of the important oilseed crops which is extensively cultivated and popular among the consumers due to its mild flavour and intensively aromatic odour. Sesame is utilized as a biological supply of essential fatty acids because of its unsaturated fatty acid composition and phytochemical antioxidant content (Oboulbiga *et al.*, 2024). Sesame seeds have varying oil content, ranging from 37% to 58%, based upon the varieties and growing season. The various ecological influences that affect the composition of the seeds, particularly variations in precipitation or rainfall and light or sunlight radiation, are related to the variations in oil content of the crop. The colour and size of the seeds are also influenced by the oil content.

Nutritional profile in sesame oil

Sesame seeds are abundant in fats, vitamins, protein, minerals, and dietary fibre. Sesame oil is abundant in unsaturated fatty acids, vitamins, etc. Sesame seeds are high in minerals like Fe and Ca and have a protein content of 21.9% and fat content of 61.7%. Sesame seeds are known as the "crown of eight grains" and an "all-purpose nutrient bank" due to its high nutritious content (Wei *et al.*, 2022).

Lipids

The lipids are one of the key components in sesame, which are primarily present in the seeds. Ever since ancient times, sesame has been referred to as the "Queen of Oil" due to its highest oil content of 45–58% among the major oil crops. sesame oil contains more than 80% of

unsaturated fatty acids such as Oleic and linoleic acids; remaining amount made up of saturated fatty acids particularly palmitic and stearic acid (Ozdemir *et al.*, 2018).

The fatty acid profile shows curious amount of polyunsaturated (44.4%), and monounsaturated (40.3%) fatty acids. The fatty acids ω -3 and ω -6 operate as building blocks for eicosanoids, which control inflammation and the immune system. Sesame oil also contains several derivatives of essential fatty acids (EFAs), such as eicosapentaenoic acid, dihomo-gamma linolenic acid (DGL), and arachidonic acid (ω -6 derivatives). They are extremely significant due to their role as lipid mediators in numerous physiological processes.

Vitamins

Tocopherols, often known as vitamin E, are a class of compounds that have a completely saturated phytol chain and a 2-methyl-6-chromanol ring. There are two types of the carbon chain: one is completely saturated and is responsible for tocopherols; the other is made up of three un-saturations and is responsible for tocotrienols. The quantity and placement of methyl groups connected to the chromanol ring differentiate the various types of tocopherols (α , β , γ , and δ) from one another. Sesame Oil is widely recognized for its oxidative stability, and the tocopherol content is one of the responsible factors for oxidative stability which varied between 33 mg/100g to 101 mg / 100g as per Codex Alimentarius Standard. Tocopherol levels in sesame oil derived from black seeds are lower than those from brown or white seeds. The α -tocopherol are predominant form of vitamin E in tissues of humans and animals but they require γ -tocopherol which is abundantly present in sesame oil (Fasuan *et al.*, 2018).

Mineral composition

The mineral fractions present in 100gram of sesame seeds which are listed in the following table.

Minerals	mg / 100 g of seeds
K	525.9
P	516
Mg	349.9
Na	15.28
Fe	11.39
Zn	8.87
Mn	3.46

Antinutrients

Antinutrients are compounds that interfere with or block the body's ability to digest and absorb the nutrients, which has a detrimental effect on an animal's development and health. Oxalic and phytic acids, together with trace levels of tannins, are the primary antinutritional components of sesame seeds. At present, the oxalic acid range values in sesame meal reported rarely. The oxalic and phytic acid accounts 13 % and 1.12 % in sesame hulls respectively (Farran *et al.*, 2000).

Lignans

Lignans are a class of naturally occurring compounds that are extensively distributed as minor molecules in the kingdom of plants and are characterized as an oxidative coupling product of β -hydroxyphenylpropane. Sesame oil is renowned for being extremely resistant to oxidative rancidity and having a long shelf life, despite having approximately 85% unsaturated fatty acids. This particular stability has been linked to lignans in addition to the existence of tocopherols. Sesamol (147.12–202.92 mg/100 g), sesamin (344.19–393.25 mg/100 g), and sesamol (70,00–610,00 mg/100 g) are the three primary sesame oil lignans (Dar *et al.*, 2019). Black seeds have a high sesamol to sesamin ratio.

Quality index for edible oil

Colour

Colour is a biased indicator that the food industry uses quickly to assess the quality of cooking oil. The oxidation and thermal degradation of fatty acids produce pigments (non-volatile decomposition products and α -, β -unsaturated carbonyl compounds) that soak into the oil during frying and cause the color of the oil to darken. A Hunter colorimeter can be used to measure the oil's color. Depending on the cultivar, Sesame Oil can have a yellow or black color. There is a variation in color intensity between 5.8 and 8.3 Lovibond unit yellow (LUY). The temperature at which the oil is roasted has a significant impact on its color. When sesame seeds are not roasted, Sesame oils are light yellow, and when seeds are roasted, they are brown or dark brown.

Saponification value (SV)

The determination of the oxidative stability and validity of oil is commonly achieved by employing the use of fatty acid composition. The saponification value can be used to calculate the average molecular mass of fatty acids. It is stated as the quantity of potassium hydroxide (KOH) needed to saponify one gram of oil, expressed in milligrams. Lower concentrations of

linoleic and linolenic acid and higher concentrations of oleic acid make oil more stable. The deep-fried flavor is caused by 2,4-decadienal, which is produced when linolic acid breaks down. The low value indicates potential long-term conservation character.

Iodine Value (IV)

The degree of unsaturation in oil can be directly determined by looking at its iodine value (IV). Unsaturated fatty acid double bonds are halogenated with the use of iodine. The IV is expressed as the amount of absorbed iodine in centigrams. Its unsaturated state is shown in the high iodine index.

Acid value (AV)

The amount of KOH milligrams needed to neutralize the free fatty acids in one gram of oil is known as the acid value.

Peroxide Value (PV)

PV, or peroxide value, is a valuable measure of oxidation at starting stage. To calculate this value, the hydroperoxides react with potassium iodide (KI) that has been acidified to release iodine, which can then be measured volumetrically by reacting with sodium thiosulphate that has been standardized. The number is the oxygen equivalent in milliliters per kilogram of fat. The peroxide index value for sesame is $< 0.1 \text{ meq O}_2/\text{kg}$.

P-Anisidine Value

The International Union of Pure and Applied Chemistry method states that the p-Anisidine value (p-AV) is equal to 100 times the optical density measured at 350 nm in a 1 cm cell of solution containing 1 g of oil and 100 mL of a mixture of solvent and reagent. It can also refer to the proportion of non-volatile unsaturated aldehyde molecules that are produced as fatty acid hydroperoxide's subsequent breakdown products.

Total Oxidation Value

P-AV can be used to calculate the total oxidation (TOTOX) value, which is frequently utilized in the industry in conjunction with PV to get the TOTOX value.

$$\text{TOTOX value} = 2\text{PV} + \text{P-AV}$$

The TOTOX value is frequently thought to have the benefit of mixing information about the oil's historical background (as shown by the p-AV) with its current state (as shown by the PV). As a result, calculating the TOTOX value has been done widely to gauge the oxidative degradation of

dietary lipids . This number indicates the quality of the oil or fat, the degree of oxidation, and the existence of breakdown products that resulted from earlier oil oxidation (Nayak *et al.*, 2016).

Health benefits

The sesame seed oil has many health properties (Oboulbiga *et al.*, 2024) as detailed below

Antihyperlipidemic effect

Sesame Oil is an extremely intriguing oil from a dietary perspective. This oil is an excellent choice for table oil in diets meant for lowering "bad cholesterol" and avoid cardiovascular problems because of its balance of oleic acid (C18:1) and linoleic acid (C18:2). Because of its high fatty acid content, sesame oil is delicious and heart healthy. Studies on the impact of Sesame Oil have suggested that because it has a variety of PUFAs, such as sesamin and sesamol, it may be able to lower the level of bad cholesterol. These fatty acids maintain low LDL cholesterol levels and a robust circulatory system, which prevents atherosclerosis. Recent research on this oil has demonstrated the function of oleic acid in the lipoprotein-mediated metabolism of circulating cholesterol. It lowers the risk of atherogenesis by causing a decrease in LDL cholesterol and a rise in HDL cholesterol in tandem. It can stop LDL-cholesterol from oxidizing and has antilipolytic actions on the body. Its ability to decrease cholesterol is associated with phytoestrogen, which also lowers TC, TG, VLDL, and LDL while raising HDL. Sesamin mostly has antihyperlipidemic effects from sesame oil. Monounsaturated fatty acids (MUFA) may be useful in preventing atherosclerosis and dyslipidemia. Eicosapentaenoic (EPA) and docosahexaenoic fatty acids are involved in hypotriglyceridemic effect. Sesamin, active compounds present in sesame oil have the antinociceptive and anti-inflammatory properties.

Antioxidant potential

Strong antioxidants include the lignans, tocopherols (vitamin E), and phytosterols found in sesame oil. In order to lower the chance of acquiring chronic illnesses, these substances scavenging free radicals in the body. Sesame oil has cardioprotective qualities and is a great source of PUFAs. Its high concentration of these fatty acids contributes to its outstanding oxidative stability. Sesame oil brute has antioxidant qualities while having a very small quantity of sesamol. In non-heated oil, sesaminol seems to have antioxidant activity similar to that of sesamol. Vitamin E, an antioxidant that guards against oxidation of cell membranes, is found naturally in sesame oil. It shields the skin from environmental aggressors like UV rays. Sesamin,

sesamol, and sesaminol are additional naturally occurring antioxidants that may be useful for cell reconstitution. Sesamin and sesamol, two uncommon components of the oil, offer sesame oil a remarkable antioxidant activity and, consequently, a great durability against oxidation. The sesame oil used in massage slows down the aging process and improves skin elasticity.

Heart health

The proportion of $\omega 3$, $\omega 6$, and $\omega 9$ fatty acids in sesame oil is balanced. Studies have indicated that eating a diet rich in these heart-healthy fats lowers the risk of heart disease. Consuming sesame oil may help reduce triglycerides and low levels of low-density lipoprotein (LDL) cholesterol, both of which are considered heart-protective factors. Lecithin's function as an emulsifier prevents cholesterol and saturated fats from building up in the arteries. Conversely, sesamin has been shown to block the activity of $\Delta 5$ -desaturase and the absorption of cholesterol; when combined with sesaminol's antioxidant properties, this has been linked to the prevention of cancer. Fungal fatty acid production is strongly inhibited by sesamol. Malic enzyme inhibition and the availability of NADPH required for this biosynthetic route appear to be the causes of this impact. The capacity of sesamol to decrease the synthesis of NADPH is what draws attention to it while researching the impact of oxidants on tumor and vascular endothelial cells.

Other health benefits of sesame oil

It can also be used to treat headaches, vertigo, and impaired vision. Indians use sesame oil as an antibacterial mouthwash to treat insomnia and anxiety. Due to a dry winter climate, sesame oil works much better than isotonic sodium chloride solution in treating dry nasal mucus. Findings have provided fresh molecular understanding of sesame oil functions and demonstrated that sesamin, the compound's main component, is responsible for all of the organization's advantages for auditory function, including the preservation of auditory cells and the correction of their defects.

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ARTIFICIAL INTELLIGENCE (AI) ROLE IN FUTURE INDIAN AGRICULTURE

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Introduction

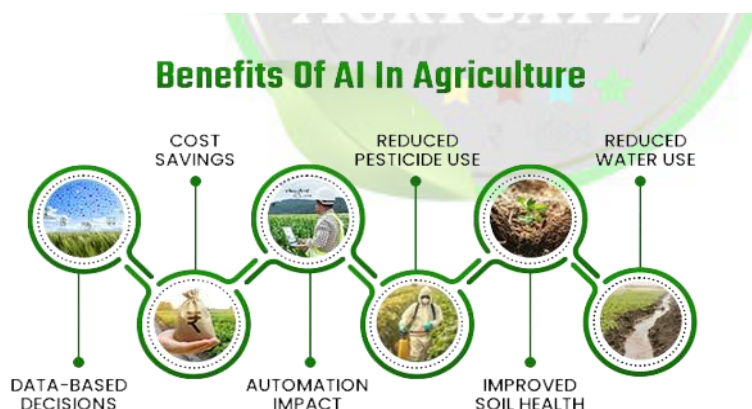
The growing world's population and the demand for food rising, it is crucial to use efficient farming methods to increase production on the limited amount of land. AI is becoming more prevalent every day in agriculture, and AI-based devices are elevating the current farming system. Agriculture is dependent on a number of variables, including soil nutrient content, moisture, crop rotation, rainfall, temperature, etc. Products based on artificial intelligence can use these variables to track crop productivity. In order to improve a wide range of agriculture-related tasks throughout the entire food supply chain, industries are turning to Artificial Intelligence technologies.



Artificial Intelligence (AI) refers to the simulation of human intelligence in machines that are designed to think, learn, and make decisions. These systems analyze vast amounts of data to recognize patterns, solve problems, and make predictions, enabling efficiency and precision across various fields, including agriculture

Applications and solutions that use AI in agriculture have been created to assist farmers in precise and regulated farming by giving them the right advice on water management, crop rotation, timely harvesting, the type of crop to be cultivated, optimal planting, pest attacks, and nutrition management. AI-enabled systems make weather predictions, monitor agricultural sustainability, and assess farms for the presence of diseases or pests and undernourished plants using data like temperature, precipitation, wind speed, and sun radiation in conjunction with photographs taken by satellites and drones.

With equipment as basic as an SMS-enabled phone and the Sowing App, farmers without connectivity may profit from AI right away. Farmers with Wi-Fi connectivity can utilise AI apps to get a constantly AI-tailored plan for their farms, in the meantime. Farmers can meet the increased demand for food while growing output and revenues responsibly and without diminishing priceless natural resources with the help of IoT and AI-driven technologies. Climate variables include heat, precipitation, wind, and solar radiation.



While human minds excel at many tasks, they have inherent limitations in accurately assessing and predicting complex patterns. In recent years, advancements in satellite technology, Geographic Information Systems (GIS), and other innovations have revolutionized fields like communication, defense, and healthcare. However, the adoption of these technologies in



agriculture has remained comparatively limited, despite its vast potential to address critical challenges faced by farmers.

Its applications span diverse sectors:

- **Healthcare:** AI enhances diagnostics, predicts patient outcomes, and streamlines treatment plans.
- **Finance:** It powers fraud detection, automated trading, and risk assessment.
- **Transportation:** Autonomous vehicles, traffic management, and logistics optimization rely heavily on AI.
- **Education:** Personalized learning platforms and virtual tutors are transforming education delivery.

AI's versatility and ability to process vast amounts of data in real time make it particularly valuable for addressing complex problems in agriculture.

AI Applications Revolutionizing Indian Agriculture

Precision Farming: A Data-Driven Approach

Precision farming, underpinned by AI technologies, allows farmers to make informed decisions about crop management. AI-powered tools analyze data from drones, sensors, and satellite imagery to optimize irrigation, fertilization, and pest control. For instance, drone-assisted aerial surveillance, equipped with advanced computer vision, enables real-time detection of crop health issues. These drones identify areas needing attention and apply pesticides or nutrients accurately, minimizing waste and environmental impact.

Crop Disease Detection for Healthier Harvests

Crop diseases have been a major cause of yield loss in India, but AI is becoming a game changer. A study published in *Computers and Electronics in Agriculture* showcased how neural networks can detect diseases like apple scabs with 95% accuracy. Similarly, machine learning algorithms have been used to identify yellow rust in wheat crops, enabling timely interventions. AI-based pest surveillance systems, like the National Pest Surveillance System, are also helping Indian farmers tackle losses caused by climate change, ensuring healthier harvests.

Automated Weed Control Systems

Weeds persistently threaten crop productivity. Traditional methods like manual weeding or chemical herbicides are labour-intensive and can harm the environment. AI-

driven systems, however, use computer vision to distinguish weeds from crops and apply herbicides selectively, reducing both cost and environmental damage.

Livestock Health Monitoring: Enhancing Productivity

AI's benefits extend to livestock management, a critical component of Indian agriculture. Advanced sensor-based systems and image recognition technologies, such as those developed by CattleEye, monitor livestock behaviour and health in real-time. These systems detect early signs of illnesses, allowing farmers to take prompt action and improve livestock productivity.

AI Robotics:

Robots that can effortlessly carry out a variety of activities in farming fields are being developed based on AI. When compared to people, these robots are trained to harvest crops more quickly and in greater quantities while controlling weeds. These robots are taught to harvest and pack crops while simultaneously inspecting the crops' quality and looking for weeds. These robots can also overcome the difficulties experienced by agricultural labourers.

Pests' detection using AI:

One of the deadliest enemies of farmers who cause agricultural damage are pests. AI systems employ satellite photos and historical data to determine whether any insects have landed and, if so, which species—such as locusts, grasshoppers, and others—have done so. AI aids farmers in their battle against pests by sending alerts to their cell phones so that farmers may take the necessary precautions and employ the necessary pest management.

Crop health monitoring using drones:

Drone technology has had a lasting effect on the productivity of India's agriculture sector. The companies like Equinox Drones provide farmers with drone-powered solutions to boost productivity in a variety of farming operations, including precision farming, livestock management, pesticide application, crop stress identification, treatment planning, plant growth monitoring, and scouting.

Government Initiatives Driving AI Adoption

The Indian government has been proactive in integrating AI into agriculture. Recently, Union Education Minister Dharmendra Pradhan announced the establishment of

three artificial Intelligence Centres of Excellence (CoEs) focused on healthcare, agriculture, and sustainable cities.

This initiative, part of the “Make AI in India and Make AI Work for India” vision, is supported by a financial outlay of Rs. 990 crore from FY 2023-24 to FY 2027-28. Among its key objectives is to empower farmers with AI-driven solutions, as demonstrated by the following projects:

- Kisan e-Mitra Chatbot: An AI-powered assistant for farmers, providing multilingual support for queries related to the PM Kisan Samman Nidhi scheme and other government initiatives.
- AI-Based Crop Health Monitoring: Leveraging satellite data, weather conditions, and soil moisture levels for comprehensive crop health assessment.
- National Pest Surveillance System: Utilizing machine learning to detect and mitigate pest-related challenges.

Conclusion

In the future, AI will help farmers evolve into agricultural technologists, using data to optimize yields down to individual rows of plants. By reducing resource wastage, enhancing productivity, and optimizing market linkages, AI can drive long-term benefits for farmers and the environment. By integrating AI into farming practices, India can enhance productivity, reduce resource wastage, and build a more sustainable agricultural ecosystem. However, realizing this potential requires substantial investments in infrastructure, digital literacy, and financial support for smallholder farmers. This is the time for policymakers, technologists, researchers, and aggrotech innovators to join forces in unlocking the transformative potential of AI for agriculture. Through collaborative efforts, we can design inclusive, scalable, and actionable solutions tailored to the needs of farmers.

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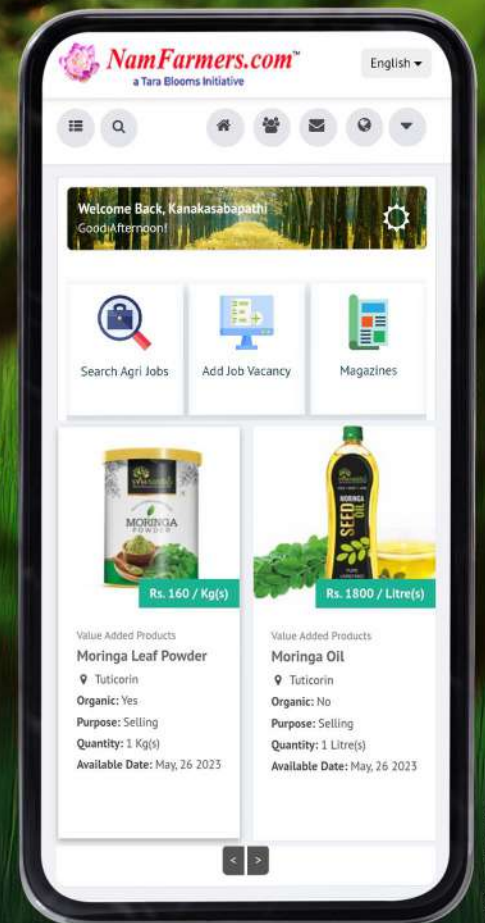
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