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ARTICLE ID: 01

WEATHER FORECASTING AND ITS IMPORTANCE IN LIVESTOCK MANAGEMENT

Introduction

Weather forecasting involves predicting atmospheric conditions in a specific location by utilizing scientific knowledge and technology to observe and analyze weather patterns. It refers to the estimation of factors such as cloudiness, precipitation, wind velocity, and temperature ahead of time (Cahir, 2013). Weather forecasting plays a vital role in modern livestock management by enabling informed decision-making based on expected atmospheric conditions, and integration of this information into livestock systems improves productivity, animal welfare, and economic sustainability.

Classification of Weather Forecasting- (IMD, Didal *et.al.* 2017)

4) **Nowcasting (Up to 6 hours)-** Provides detailed, real-time information on weather conditions, helps in immediate decision-making for sudden weather changes, such as storms or extreme temperature shifts, and short-term adjustments in animal shelter and water provision.
5) **Short-Range Forecasts (**1 to 3 days**)-** Offers detailed weather predictions for the upcoming days, including temperature, precipitation, wind speed, and humidity, which helps planning daily farm activities, such as feeding, grazing, and moving livestock. Preparing for anticipated weather events, such as heatwaves, cold snaps, or heavy rain.
6) **Medium-Range Forecasts (**3 to 7 days**)-** Provides weather outlooks for the next week, with a moderate level of detail and accuracy, which helps in scheduling weekly farm operations and activities and preparing for medium-term weather events.

Key Elements of Weather Forecasts

Elements	**Instruments**	**Units**
Precipitation	Rain gauge	mm/d
Temperature	Thermometers	°C/°F
Wind velocity	Anemometers	km/hr
Wind direction	Wind vanes	Degree (0 to 360)
Atmospheric pressure	Barometers	mm of Hg/pascals
Humidity	Hygrometers	Percentage
Sunshine hour	Sunshine recorder	hrs
Solar radiation	Radiometers/Pyrometers	W/m^2

4) **Long-Range Forecasts (**1 to 4 weeks**)-** Offers broader weather trends and patterns with less detail and lower accuracy than shorter-range forecasts, which helps in planning for future farm management practices, such as planting and harvesting feed crops. Anticipating longer-term weather impacts on livestock health and feed availability.
5) **Extended Range Forecasts (**1 to 3 months**) -** Provides general weather patterns and trends, focusing on anomalies and shifts in usual weather conditions, which helps in strategic planning for seasonal changes, such as adjusting feed inventory and shelter requirements, and preparing for potential climate-related risks, like droughts or prolonged wet periods.
6) **Seasonal Forecasts (**3 months to 2 years**)-** Offers predictions about seasonal climate patterns, such as El Niño or La Niña events, which can significantly impact weather conditions, helping in Long-term farm planning and risk management, and making decisions about breeding cycles, feed production, and resource allocation.
7) **Climate Projections (**Decades to centuries**)-** Provides insights into long-term climate trends and potential changes due to global warming and other factors, helping in developing sustainable farming practices and infrastructure investments, and preparing for long-term shifts in weather patterns and their impact on livestock farming.

Organizational Structure (shown in Fig. 1)

Weather forecasting in India is primarily operated by the India Meteorological Department (IMD), which operates under the Ministry of Earth Sciences (MoES). It is the apex agency responsible for weather forecasting, climate monitoring, and seismology.

Fig 1. Operational flow of weather forecasting agencies to end users (IMD)

National Weather Forecasting Centre (NWFC) - Located in New Delhi, the NWFC is responsible for issuing all-India severe weather forecasts and warnings.

Regional Meteorological Centers (RMCs) - IMD operates six RMCs located in Chennai, Mumbai, Kolkata, Nagpur, New Delhi, and Guwahati, which are responsible for regional weather forecasting, data collection, and issuing weather alerts for their respective regions.

Meteorological Centers (MCs) - There are several state-level Meteorological Centers that function under the RMCs. They are responsible for local weather observations, forecasts, and disseminating information to the public and local authorities.

Climate Research & Services, Pune - Maintain long-term authenticated meteorological records and provide the data series for research and national building activities.

They run the **Agricultural Meteorology Division** in collaboration with ICAR, State Agriculture Universities, State Department of Agriculture, etc.

Methodology/Procedure - Weather forecasting in India is a complex process involving the collection, analysis, and interpretation of a wide range of data as follows.

1. **Data Collection:** Includes surface, upper-air, satellite, radar, and marine observations.
2. **Data Processing:** Incorporates quality control, integration, and numerical weather prediction (NWP) models.
3. **Forecast Generation:** Short, medium, and long-term predictions.
4. **Dissemination:** Through public communication, specialized bulletins, and warning systems.
5. **Monitoring & Feedback:** Real-time updates and forecast verification.

Importance of Weather Forecasting in Livestock Management-

1) **Health and Welfare of Animals -** Accurate weather forecasts enable farmers to take proactive measures to protect their animals from extreme weather conditions like heatwaves, cold snaps, storms, and heavy rainfall. Certain weather conditions can exacerbate the spread of diseases among livestock. For instance, wet and humid weather can increase the risk of foot rot in sheep and cattle.
2) **Optimizing Feeding and Grazing -** Weather forecasts help in planning grazing schedules, like anticipating drought conditions allows farmers to manage pastures more effectively and prevent overgrazing. Knowing the weather helps in deciding when to harvest and store feed to ensure it remains dry and mold-free.
3) **Breeding and Reproduction -** Forecasts can help in scheduling breeding activities by predicting favorable weather conditions for optimal reproductive performance, with assist in managing pregnant livestock by forecasting conditions that could impact birthing or neonatal care.
4) **Reducing Financial Risks –** After knowing the extreme weather events, farmers can reduce the risk of loss, which directly impacts their financial stability. Accurate weather data can support insurance claims in case of weather-related losses, ensuring that farmers receive appropriate compensation.
5) **Operational Efficiency -** Weather forecasts assist in planning daily activities, such as moving livestock to different pastures, ensuring that these tasks are done under favorable conditions. Planning the transportation of livestock to markets or other farms becomes more efficient and safer when weather conditions are considered.
6) **Pasture and Grazing Management -** Helps in planning grazing schedules and pasture rotations based on weather conditions that affect the availability and growth of pasture.
7) **Resource Management -** Helps to manage water resources, which are critical during

drought periods. Farmers can plan water usage and storage based on expected rainfall. It can help in optimizing the use of energy resources, such as heating and cooling systems in barns and other animal housing.

8) **Welfare and Comfort -** Assists in implementing measures to maintain the comfort and well-being of livestock, such as providing shade, ventilation, or heating based on weather forecasts and anticipating and managing behavioral changes in livestock that might be triggered by adverse weather conditions.

9) **Housing and Shelter** - Provides information to ensure that housing and shelters are adequately prepared for upcoming weather conditions, such as rain, snow, or extreme temperatures. Helps in planning for adequate ventilation, bedding, and insulation to maintain a comfortable environment for livestock.

10) **Record Keeping and Analysis -** Integrates weather data with livestock health and productivity records to analyze trends and improve management practices and uses historical weather data and forecasting trends to refine livestock management strategies and improve future planning.

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Nano Urea: A Sustainable Alternative to Conventional Fertilizers for Indian Agriculture

Abstract
India has been one of the largest consumers of chemical fertilizers, especially urea, to improve crop production. However, the overuse of conventional urea has caused serious problems such as soil degradation, water pollution, reduced fertilizer efficiency, and higher subsidy costs. To overcome these issues, India has introduced Nano Urea, an innovative liquid fertilizer developed by the Indian Farmers Fertilizer Cooperative (IFFCO). Nano Urea improves nitrogen use efficiency, reduces wastage, and supports eco-friendly farming. This article highlights why India is promoting Nano Urea and how it benefits crops and farmers.

Introduction
Urea is the most commonly used nitrogen fertilizer in India due to its low cost and high availability. Unfortunately, farmers often apply more than the recommended dose, leading to poor nitrogen absorption by plants. Conventional urea provides only **30–40% nitrogen efficiency**, while the rest is lost through leaching, volatilization, or runoff. This not only reduces crop productivity but also pollutes soil and water resources.
India also spends billions of rupees every year on fertilizer subsidies and urea imports. To reduce economic burden and protect the environment, India is now promoting **Nano Urea**. Developed using nanotechnology, Nano Urea is applied as a liquid spray that delivers nitrogen directly to plant leaves. It increases efficiency, improves crop yield, and reduces fertilizer dependency.

Why India Is Promoting Nano Urea
1. Higher Nitrogen Use Efficiency
- Conventional urea has low efficiency because most nitrogen is lost before plants can absorb it.
- Nano Urea delivers nitrogen at the cellular level, increasing efficiency to **70–80%**.

2. Cost-Effective for Farmers
- One 500 ml bottle of Nano Urea can replace a **45 kg bag of conventional urea**.
- Reduces transportation, storage, and labour costs for farmers.

3. Reducing Fertilizer Subsidy Burden
- India spends more than ₹1 lakh crore annually on fertilizer subsidies.
- By promoting Nano Urea, dependency on conventional urea imports decreases, saving foreign exchange.

4. Environmental Protection

- Overuse of urea causes water pollution, soil degradation, and greenhouse gas emissions.
- Nano Urea minimizes nitrogen losses and promotes climate-smart farming.

5. Farmer-Friendly Technology

- Easy to spray and handle compared to heavy urea bags.
- Reduces drudgery for farmers and ensures better yield with smaller quantities.

How Nano Urea Helps Crops

- **Wheat and Rice**: Improves tillering and grain filling, leading to higher yield.
- **Maize and Millets**: Enhances photosynthesis and biomass growth.
- **Vegetables**: Improves leaf colour, flowering, and fruit size.
- **Sugarcane and Cotton**: Supports healthy growth and improves recovery rate of juice/fibre.
- **Pulses and Oilseeds**: Enhances pod setting and seed quality.

Field trials conducted by IFFCO and agricultural universities across India have shown that crops treated with Nano Urea had **10–15% higher yields** compared to conventional practices.

Government Initiatives

- The Government of India approved large-scale production of Nano Urea in 2021.
- IFFCO plants in Gujarat and Uttar Pradesh are manufacturing millions of bottles each year.
- Farmers are being educated through training programs, demonstrations, and awareness campaigns.
- The government aims to reduce conventional urea usage by at least 20–25% by replacing it with Nano Urea.

Challenges in Adoption

- Lack of awareness among small and marginal farmers.
- Initial hesitation to replace conventional urea.
- Requirement of proper spraying equipment for application.
- Need for continuous extension and field-level demonstrations.

Conclusion

Nano Urea is a revolutionary step towards sustainable agriculture in India. It addresses the problems of low nitrogen efficiency, soil degradation, and high fertilizer subsidy burden. For farmers, it reduces input costs while improving crop productivity. For the nation, it reduces import dependency and environmental risks. With proper awareness and large-scale adoption, Nano Urea can transform Indian farming into a more sustainable, eco-friendly, and self-reliant system.

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ARTICLE ID: 03

SHAHI LITCHI OF BIHAR: FARMERS' PRIDE AND FUTURE OPPORTUNITIES

Abstract

Bihar is the leading state of India in litchi production, especially known for the world-famous **Shahi litchi of Muzaffarpur**. This fruit is not only a source of income but also a cultural identity for Bihar's farmers. However, challenges such as old orchards, climate change, poor storage, and weak marketing reduce farmers' profits. With modern techniques, collective farmer action, and better government support, litchi farming can become more profitable and sustainable. This article explains the importance of litchi in Bihar, simple cultivation steps, challenges faced by farmers, local success stories, market opportunities, and future possibilities.

Keywords

Litchi, Bihar, Shahi Litchi, Farmers, Cultivation, Market, Future Opportunities

Introduction

Litchi is one of the most important fruits of Bihar. Muzaffarpur, also known as the **"Litchi Capital of India"**, is especially famous for the Shahi litchi variety. Nearly half of Bihar's litchi production comes from this district alone. This fruit provides income, employment, and recognition to thousands of rural families.

In my opinion, litchi farming is not just an agricultural activity — it is a way of life for many people of Bihar. It connects the farmers of the state with national and international markets. This article highlights how litchi is grown, the problems farmers face, and how proper support can make the future brighter.

Cultivation Practices in Simple Steps

Farmers of Bihar have been growing litchi for generations. Traditional wisdom, along with modern practices, can improve production. Some simple steps include:

- **Soil and Climate:** Fertile, well-drained soil and warm climate are best. Avoid waterlogging.
- **Planting:** June–July is the best time for planting. Farmers keep 8–10 meters distance between trees.
- **Irrigation:** Drip irrigation saves water and improves yield compared to flood irrigation.
- **Manure and Fertilizer:** Cow dung, compost, and organic manures improve soil health.
- **Pruning:** Cutting extra branches allows sunlight and reduces pest attack.
- **Pest Control:** Neem oil and safe sprays are commonly used to manage borers and aphids.
- **Harvesting:** The fruit is harvested in May–June when sweetness is highest.

Problems in Litchi Farming

Despite its importance, farmers face many challenges in litchi cultivation:

- **Old Orchards:** Many trees are old and less productive.
- **Climate Stress:** Irregular rainfall and heat waves reduce flowering and fruit quality.
- **Storage Issues:** Lack of cold storage and pack houses causes heavy post-harvest losses.
- **Market Intermediaries:** Middlemen take a big share of the profit.
- **Weak Farmer Groups:** Unlike other states, Bihar's litchi farmers are not strongly organized.

Possible Solutions

In my view, if farmers and government work together, these problems can be solved:

- Replant old orchards with new, high-yielding varieties.
- Provide cold storage and pack houses near villages.
- Train farmers in organic and water-saving methods.
- Form farmer cooperatives to reduce the role of middlemen.
- Start processing industries for juice, pulp, and dried litchi.
- Use digital platforms like **Kisan e-mart** to sell directly to buyers.

Problems and Solutions at a Glance

Problems	Solutions
Old orchards	Replant with new varieties
Climate change	Water-saving irrigation, organic practices
Post-harvest losses	Cold storage and pack houses
Middlemen control	Farmer cooperatives, direct marketing
Weak marketing	Branding and digital platforms

Success Story of Farmers

A cooperative group of farmers in **Muzaffarpur** recently exported **250 tonnes of litchi** directly to big cities through air cargo. This increased their income by 25%. Farmers like Sunita Devi, who joined the group, earned much more compared to selling through middlemen.

This story shows how **unity and modern marketing can change farmers' lives**. If more farmers join together, they can directly reach better markets and improve their earnings.

Market and Export Potential

Most litchis from Bihar are sold fresh in local and metro markets. But less than 2% is exported because of poor storage and logistics. With more **cold storage, processing units, and branding**, the Shahi litchi of Bihar can easily reach international markets. Products like pulp, juice, and dried litchi have great demand and can provide additional income to farmers.

Future Opportunities

The future of litchi farming in Bihar is **very bright**. The Shahi litchi already has a **Geographical Indication (GI) tag**, which helps in branding and international recognition. If farmers adopt modern methods, work in cooperatives, and use digital marketing, Bihar's litchi can become as famous globally as mango.

I believe more youth should join horticulture and agri-business related to litchi. This will create rural jobs, reduce migration, and make farming more attractive for the next generation.

Conclusion

Litchi is not just a fruit — it is the pride of Bihar and the hope of thousands of farmers. By mixing traditional wisdom with modern techniques, farmers can increase productivity and profits. If proper attention is given to marketing, storage, and farmer unity, the **Shahi litchi of Bihar** can shine not only in Indian markets but also in global markets.

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Parthenium Weed: A Threat To Agriculture, Environment and Health

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Abstract

Parthenium hysterophorus, commonly known as Congress Grass or Carrot Weed, is an foreign species that has become a major concern in India and some states are more seriously affected. This weed adversely affects human health, agriculture, livestock, and the environment. It causes severe skin allergies, asthma, and respiratory issues in humans. In agriculture, it competes with crops for nutrients and water, thereby reducing yields and soil fertility. For livestock, it contaminates fodder and causes diseases, resulting in decreased milk production. Each plant produces thousands of seeds, making eradication difficult. This article discusses the harmful effects of Parthenium and highlights possible control methods such as mechanical control, cultural removal, biological control, chemical sprays and IWM. Awareness campaigns and community participation are crucial in managing this weed effectively.

Introduction

Parthenium hysterophorus is one of the most aggressive exotic weeds in India. It originated unintentionally and has spread across farmlands, open spaces, roadsides, and grazing areas. Popularly called Congress Grass, this weed is considered highly dangerous because it affects human health, crop production, soil quality, livestock, and biodiversity. Its rapid growth and ability to produce thousands of seeds per plant make it extremely difficult to control.

Impact on Human Health

Parthenium releases airborne pollen and toxic chemicals that trigger allergies and respiratory problems. People exposed to this weed often develop eczema, skin rashes, asthma, and hay fever. The pollen can travel long distances, affecting both rural and urban populations. Medical reports since the 1950s suggest that the spread of Parthenium has significantly contributed to rising cases of asthma and skin diseases in India.

Agricultural and Environmental Impact

Parthenium competes with crops for sunlight, water, and soil nutrients, reducing crop yields by up to 40%. It poisons the soil through allelopathic effects, which suppress the growth of nearby plants. This has severe consequences for farmers as fertile soil becomes less productive over time.

In grazing lands, Parthenium contaminates fodder, leading to mouth ulcers, skin problems, and reduced milk production in cattle. Its aggressive spread also threatens native biodiversity, as it invades natural ecosystems and reduces the availability of useful pasture grasses.

How it is reducing yield

Parthenium weed reduces crop yield mainly by competing with crops for essential resources such as water, nutrients, and sunlight. It grows very quickly and overshadows nearby plants, which reduces their ability to carry out photosynthesis. In addition, the weed releases toxic chemicals into the soil, a process known as allelopathy, which prevents the germination and growth of other plants. Continuous infestation also lowers soil fertility, making the land less productive over time. In grazing areas, Parthenium replaces nutritious fodder grasses, which affects livestock health and milk yield. Altogether, these effects cause a significant reduction in crop production and farm income.

Which states mostly affected

Parthenium weed is spread all over India, but some states are more seriously affected because of their climate, soil conditions, and farming systems.States Mostly Affected by Parthenium Weed in India:

- Karnataka – heavily infested in both agricultural fields and grazing lands.
- Andhra Pradesh & Telangana – spread along roadsides, wastelands, and crop areas.
- Maharashtra – widespread in cultivated fields and fallow lands.
- Madhya Pradesh – one of the worst affected states, especially in soybean and wheat areas.
- Uttar Pradesh – large-scale infestation along riverbanks, fields, and rural roads.
- Tamil Nadu – seen in dryland farming areas and near towns.
- Chhattisgarh & Odisha – spreading in both forests and agricultural regions.
- Punjab & Haryana – mostly along canals, roadsides, and crop fields.

Methods of Control :

Mechanical Methods

- Hand weeding before flowering to prevent seed spread. But this is not recommended since it might cause serious health hazard. Further, the seeds may drop off and increase the area of infestation.

- Ploughing the weed into the soil before it flowers and growing pasture grasses or other crops can help control it.

- Village-level awareness and community participation for large-scale removal.

Biological Control

- The leaf feeding beetle (Zygogramma bicolorata) feeds on Parthenium leaves and is used as a biological control agent.(Introduced form Mexico)

- This eco-friendly approach has shown promising results in reducing weed populations.

- The stem galling moth (Epiblema strenuana) introduced form Mexico has been established in all Parthenium dominated areas. The moth's larvae feed on the stem of the weed and forms ball which inhibit the plant growth by one adult for one plant.

Cultural Control

- Crop Rotation: Growing competitive crops like sorghum, maize, and cowpea helps suppress the growth of Parthenium.

-Mulching: Covering the soil with crop residues, straw, or plastic sheets prevents the weed seeds from germinating.

- Improved Pasture Management: Sowing fast-growing grasses (e.g., *Stylosanthes*, *Cenchrus*, *Guinea grass*) reduces space for Parthenium to establish.

- Timely Sowing and Intercropping: Early sowing of crops and mixed cropping with legumes helps reduce weed population by minimizing empty spaces.

- Manuring and Fertilization: Adequate organic manure and fertilizers strengthen crop growth, making them more competitive against weeds.

Chemical Control

- Spraying 2,4-D sodium salt (0.2%) or Glyphosate (1%) effectively controls the weed at early growth stages.

- Repeated spraying may be required every 40–45 days for sustained control.

- Note : Using chemical herbicides has several drawbacks. They can cause serious environmental problems, and weeds may also develop resistance to many commonly used herbicides such as atrazine, 2,4-D, metribuzin, paraquat (Gramoxone), trifluralin, diphenamid, and glyphosate.

Integrated weed management[IWM]

- Integrated weed management of Parthenium means using a mix of methods such as manual removal, cultural practices, chemical sprays, and biological agents instead of relying on a single approach.
- This combined strategy is more effective, economical, and eco-friendly for long-term control.
- Community participation and the use of competitive pasture plants along with biological control have shown good results in several regions, making integrated management the best option for sustainable control of Parthenium.
- An integrated approach is the most sustainable solution for managing Parthenium in the long run.

Conclusion

Parthenium is more than just a weed—it is a public health hazard, agricultural threat, and ecological problem. Managing its spread requires integrated control methods and active participation from farmers, scientists, and local communities. Awareness campaigns such as Parthenium Awareness Week (August 16–22) play a vital role in educating the public about its harmful effects and control measures. By combining mechanical, biological, cultural, chemical methods, and integrated weed management[IWM] and it is possible to reduce the impact of this invasive weed and protect agriculture, livestock, and human health.

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HOW RENEWABLE ENERGY HELPS AGRICULTURE MORE THAN NON-RENEWABLE ENERGY

Abstract

Agriculture depends on energy for irrigation, tillage, harvesting, storage, processing, and transportation. For decades, farmers have used non-renewable energy such as diesel, coal, petrol, and natural gas. These sources are costly, limited, and harmful to the environment. Renewable energy sources like solar, wind, biogas, and hydropower are eco-friendly, cost-effective in the long run, and more reliable for rural areas. This paper explains the importance of renewable energy in agriculture, the challenges of non-renewable energy, and the reasons why farmers must shift to sustainable solutions.

Keywords

Renewable energy, Non-renewable energy, Sustainable agriculture, Farmers, Solar power, Biogas, Climate change

Introduction

Energy is a basic input in farming. From preparing the soil to transporting produce to markets, every step requires energy. For many years, farmers have depended on fossil fuels and electricity from coal. These sources have supported farming, but they bring serious problems: rising costs, pollution, climate change, and long-term unsustainability.

Renewable energy provides a better path. Solar pumps, windmills, biogas plants, and mini-hydro systems are being adopted by farmers across India. They are cheaper over time, do not cause pollution, and are suitable for remote villages. This article explains the difference between renewable and non-renewable energy in agriculture and highlights why green energy is essential for the future of farming.

Non-Renewable Energy in Agriculture

Non-renewable energy is energy that comes from sources which will run out one day, such as coal, diesel, petrol, and natural gas.

Uses in farming

- Diesel is used in tractors, harvesters, and irrigation pumps.
- Electricity from coal is used for tube wells, cold storage, and processing units.
- Natural gas is used to make fertilizers such as urea and DAP.
- LPG and coal are sometimes used for drying food products.

Problems with non-renewable energy

1. **High cost** – Prices of diesel, petrol, and coal rise every year, making farming expensive.
2. **Limited supply** – Fossil fuels are depleting and cannot be replaced quickly.
3. **Pollution** – Burning fuel releases smoke and harmful gases, leading to climate change.
4. **Soil and water stress** – Chemical-based farming supported by fossil energy reduces soil fertility and increases water pollution.

Renewable Energy in Agriculture

Renewable energy comes from sources like the sun, wind, water, and organic waste. These sources are unlimited, clean, and available everywhere.

Types and uses

- **Solar energy** – Solar water pumps for irrigation, solar dryers for crops, solar cold storages, and solar fencing.
- **Wind energy** – Windmills for pumping water, wind turbines for generating electricity.
- **Biogas** – Cow dung and crop residues used for cooking fuel, electricity, and organic fertilizer.
- **Mini hydropower** – Small rivers and canals used to generate electricity in hilly areas.

Why Farmers Must Shift to Green Energy

Farmers must move towards renewable energy because:

- It reduces dependence on costly fossil fuels.
- It ensures reliable power in villages where electricity supply is weak.
- It protects the environment for future farming.
- It allows long-term savings by cutting fuel and electricity bills.

Green energy also gives farmers more independence, as they are less affected by market fuel prices or power shortages.

Role of Solar Energy in Irrigation

Solar pumps are one of the most successful renewable energy solutions in agriculture. In states like Rajasthan, Gujarat, and Haryana, thousands of farmers use solar pumps for irrigation. These pumps:

- Provide free water after installation.
- Work even in remote villages without grid electricity.
- Reduce the use of diesel pumps, saving thousands of rupees every year.

Solar-powered cold storage units are also helping farmers reduce post-harvest losses of vegetables, fruits, and milk.

Benefits of Biogas for Small Farmers

Biogas plants use cattle dung and crop residues to produce gas for cooking, lighting, and even running engines. The leftover slurry is a very good organic fertilizer.

Advantages:

- Saves money on LPG and fertilizers.
- Provides clean fuel at home.
- Improves soil health and crop productivity.

Biogas is especially useful for small and marginal farmers with livestock.

Impact on Climate and Soil Health

Non-renewable energy causes climate change by releasing greenhouse gases like carbon dioxide. This results in irregular rainfall, droughts, and floods that harm farming. It also increases pest attacks and reduces crop yields.

Renewable energy reduces pollution and helps farmers adapt to climate change. Biogas slurry improves soil fertility, and reduced use of chemicals protects soil and water for future generations.

Cost Factors in Energy Use

- **Non-renewable energy**: High recurring costs due to rising prices of diesel and petrol. Farmers spend a big part of their income on fuel and electricity bills.
- **Renewable energy**: Requires investment at the beginning, but operating cost is very low. Over time, farmers save more money.

Why Renewable Energy is Cheaper in the Long Run

Though installing solar panels or biogas plants requires money, they last for many years and provide almost free energy.

- A solar pump can work for 20 years without fuel cost.
- A biogas plant provides free cooking gas and fertilizer.
- Wind turbines and mini-hydro plants produce electricity without recurring costs.

Thus, renewable energy is more cost-effective in the long run compared to diesel or coal-based power.

Government Policies Supporting Renewable Energy in Agriculture

The government of India has introduced several schemes to support farmers:

- **PM-KUSUM scheme** – Subsidy for installing solar water pumps.
- **Biogas development programs** – Support for family and community biogas plants.
- **State-level schemes** – Financial aid for solar dryers, cold storages, and fencing.
- **Low-interest loans** – Available for renewable energy projects in rural areas.

These initiatives reduce the initial cost burden and encourage farmers to adopt clean energy.

Success Stories from Indian Villages

- In **Rajasthan**, farmers using solar pumps save thousands of rupees on diesel every season.
- In **Maharashtra**, villages with biogas plants cook food with clean gas and use slurry as fertilizer.
- In **Tamil Nadu**, wind energy projects support irrigation and rural electrification.
- In **Bihar and Uttar Pradesh**, solar cold storages help farmers store onions and potatoes safely.

Challenges in Adopting Renewable Energy

- High initial investment for solar or wind systems.
- Lack of awareness among farmers about renewable technologies.
- Limited technical support and maintenance in rural areas.

With proper training, demonstration projects, and government subsidies, these challenges can be solved.

Future of Renewable Energy in Agriculture

The future of farming in India depends on renewable energy. As technology becomes cheaper, adoption will increase. Farmers will benefit from reduced costs, better soil health, and protection against climate risks. Renewable energy will make agriculture sustainable, eco-friendly, and profitable.

Comparison of Renewable and Non-Renewable Energy in Farming

Point	Renewable Energy	Non-Renewable Energy
Source	Sun, wind, water, biomass	Coal, diesel, petrol, natural gas
Availability	Unlimited, sustainable	Limited, will finish one day
Cost	Low after setup	Increasing every year
Pollution	Clean and eco-friendly	High pollution, climate change
Village support	Works well in rural areas	Often shortage of supply
Long-term use	Safe for future generations	Not sustainable

Conclusion

Renewable energy is more helpful for agriculture than non-renewable energy. It saves money, reduces pollution, and improves soil and water quality. By adopting solar, wind, and biogas, farmers can secure their livelihood and protect the environment. Government policies and farmer awareness will play a key role in this transition. The future of farming lies in renewable energy, which ensures sustainability, profitability, and food security for future generations.

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ARTICLE ID: 06

MAGNETOPONICS: A REVOLUTIONARY WAY TO GROW CROPS WITHOUT SOIL

Introduction:

Imagine walking into a high-tech greenhouse where plants seem to float in mid-air, growing without soil, and thriving in a mist of nutrients. This isn't science fiction—it's a real innovation called magnetoponics. It's an exciting, futuristic farming method that combines magnetopriming and aeroponics to create a soil-free, efficient, and environmental-friendly way to grow crops.In a world where traditional agriculture faces challenges like climate change, urbanization, and soil degradation, magnetoponics offers a promising alternative. Using magnetic fields to levitate seeds and growing them in mist rather than soil, this method provides a more controlled environment for plants, leading to healthier growth and higher crop yields.

2. What is Magnetoponics?

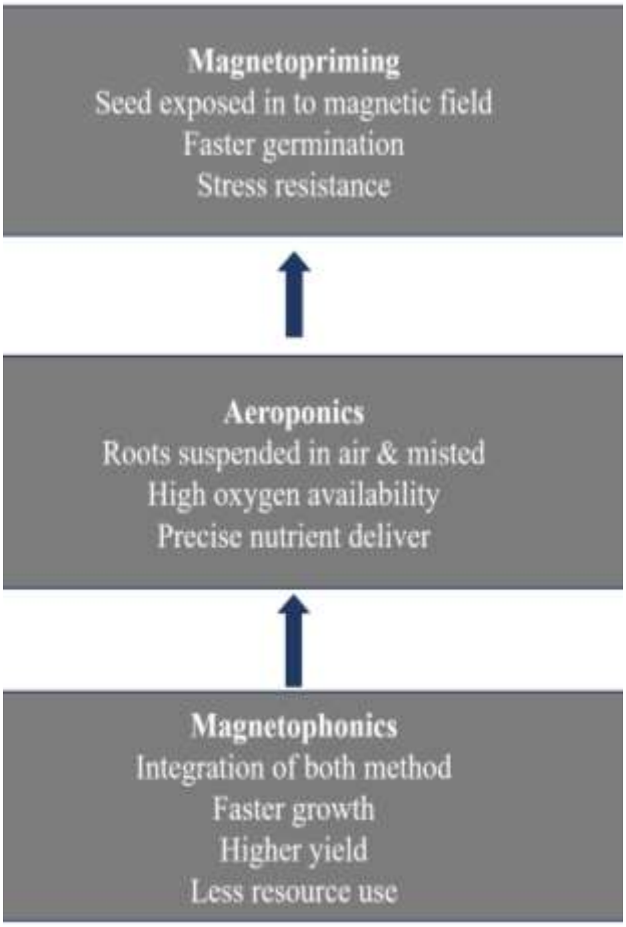
At its core, magnetoponics is about growing plants without the need for soil, using a blend of two fascinating technologies: magnetopriming and aeroponics.

2.1 Magnetoponics: Enhancing Seed Growth with Magnetism

Magnetoponics is an emerging agricultural innovation that merges two complementary high-tech farming techniques—magnetopriming and aeroponics—to create an optimized growth environment where plants develop without ever touching soil. This approach not only accelerates germination and improves plant health but also significantly reduces resource use, making it a promising solution for sustainable agriculture in challenging environments.

The process begins with magnetopriming, a seed enhancement method in which seeds are exposed to precisely calibrated magnetic fields before planting. These magnetic fields induce subtle but highly beneficial biochemical and physiological changes within the seeds. Scientific studies have shown that such exposure can activate critical growth enzymes, increase membrane permeability, and enhance the efficiency of water uptake (Florez et al., 2007). These changes lead to faster and more uniform germination—often 25–30% quicker compared to untreated seeds—and promote robust early root development. In addition, magnetopriming stimulates hormonal responses that increase the plant's resilience to environmental stress factors such as drought, soil salinity, and temperature extremes (Aladjadjiyan, 2010). By ensuring that seeds begin life with an internal "biological boost," magnetopriming lays a strong foundation for the next phase of magnetoponics.

Once seeds are magnetoprimed, they are transferred into an aeroponic system, a soilless cultivation method in which plants grow with their roots suspended in air rather than embedded in soil or submerged in water. Instead of relying on a traditional substrate, the aeroponic setup nourishes the plants by spraying their roots with a fine mist of nutrient-rich solution, delivered through high-pressure nozzles or ultrasonic foggers. This constant exposure of roots to air maximizes oxygen availability, a factor critical for cellular respiration and overall plant vigor. At the same time, the nutrient mist ensures precise delivery of essential minerals, reducing waste and preventing nutrient leaching into the environment. Because the solution is applied directly to the roots, aeroponics can reduce water consumption by up to 90% compared with conventional soil-based farming (Sharma et al., 2018).



By integrating magnetopriming and aeroponics into one seamless system, magnetoponics combines the early developmental advantages of magnetic stimulation with the ongoing efficiency and precision of aeroponic feeding. The seeds enter the aeroponic chamber already primed for rapid growth, and the controlled environment sustains that advantage throughout the plant's life cycle. Factors such as humidity, temperature, and nutrient composition can be precisely monitored and adjusted in real time, ensuring optimal growth conditions. This dual-technology approach results in plants that are healthier, more uniform in size, and ready for harvest in a shorter time frame than traditional agricultural systems allow.

In addition to boosting productivity, magnetoponics has significant environmental benefits. It eliminates the need for soil, thereby avoiding soil erosion, contamination, and compaction. It also reduces the risk of soil-borne pathogens and pests, decreasing reliance on chemical pesticides. In an era where sustainable food production is becoming increasingly urgent due to climate change, resource scarcity, and population growth, magnetoponics represents a forward-thinking, resource-efficient agricultural strategy that could reshape the future of farming both on Earth and in extraterrestrial environments.

3. Where Magnetoponics Can be Used?

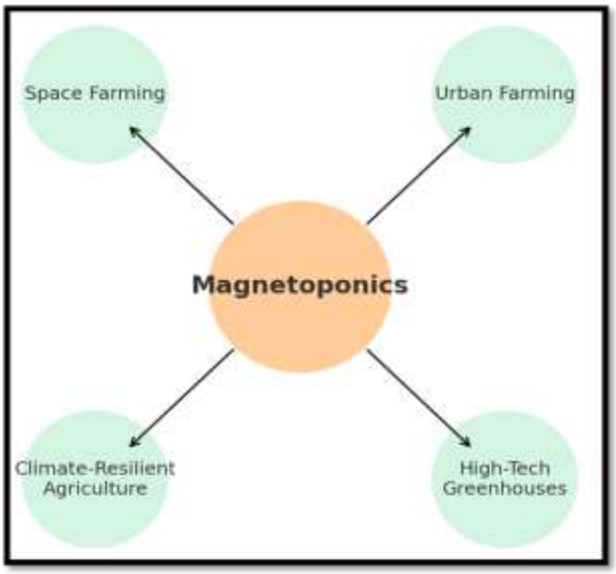
Magnetoponics has a wide range of applications, from urban farming to space exploration.

3.1 Urban Farming

In crowded cities, space is at a premium. Magnetoponics allows for vertical farming, where crops can be grown in multi-tiered chambers, maximizing the use of available space. It's perfect for rooftops, basements, or even unused office buildings, providing fresh food right in the heart of the city.

3.2 Space Farming

One of the most exciting potential applications of magnetoponics is in space exploration. NASA has shown interest in using aeroponics and magnetic levitation to grow food in zero gravity. Magnetoponics could allow astronauts to grow their own food in space, reducing reliance on resupply missions from Earth.



3.3 Climate-Resilient Agriculture

In regions where soil quality is poor or water is scarce, magnetoponics offers a solution. Because it doesn't rely on soil and uses far less water, this method can be used in places where traditional farming might not be possible.

3.4 High-Tech Greenhouses

Magnetoponics is also well-suited for greenhouse environments, where crops can be grown year-round without the need for outdoor soil. This could be especially valuable in regions with harsh climates or seasonal weather changes.

4. Challenges and Limitations

While magnetoponics holds a lot of promise, there are still some challenges that need to be addressed.

4.1 High Initial Costs

Setting up a magnetoponic system requires significant investment, particularly for the electromagnetic infrastructure and the smart technology needed to control the environment. However, as the technology advances, costs are expected to decrease.

4.2 Technical Complexity

Magnetoponics requires a certain level of expertise in electromagnetic systems and plant biology. The complexity of managing the system can be a barrier for widespread adoption, but as more research is done, it's likely that user-friendly systems will be developed.

4.3 Limited Crop Types

Currently, magnetoponics works best with small, fast-growing crops like lettuce, herbs, and leafy greens. Larger crops like root vegetables or trees might not be as suitable due to their size and structural requirements.

5. The Future of Magnetoponics:

The future of magnetoponics is incredibly promising. As the technology advances, we can expect to see even more efficient systems, with improved energy efficiency, lower costs, and the ability to grow a wider variety of crops.

6. Conclusion

Magnetoponics represents the cutting edge of agricultural technology. By combining the power of magnetism and the efficiency of aeroponics, it offers a way to grow crops faster, healthier, and with far fewer resources than traditional farming methods. Whether it's in urban farms, space missions, or climate-resilient agriculture, magnetoponics is a technology that could change the way we think about food production in the future. As the world faces the challenges of feeding a growing population while dealing with climate change and limited resources, innovations like magnetoponics offer a glimpse into a more sustainable, efficient, and high-tech agricultural future.

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SEED DRYING – KEY TO BETTER GERMINATION AND HIGHER YIELD

Abstract

Seed drying is one of the most important steps in seed production and storage. Freshly harvested seeds contain high moisture, which makes them prone to fungal infection, insect damage, and loss of germination power. Proper drying reduces seed moisture to safe levels, increases storage life, and ensures better germination in the next season. This article explains why drying is important, traditional and modern drying methods, farmer-friendly low-cost practices, problems caused by wet seeds, cost-saving aspects, and the future of seed drying in sustainable agriculture. The content is written in simple English, based on farmer practices, so that it is easily understandable and useful in the field.

Keywords: Seed drying, Germination, Storage, Moisture, Farmer practices, Seed quality, Agriculture

Introduction

Seeds are the backbone of agriculture. For farmers, a seed is not just a grain – it is the future harvest and income. But the success of a seed depends not only on the variety and how it is grown in the field, but also on how it is handled after harvest.

One of the most important post-harvest steps is seed drying. If seeds are stored with too much moisture, they spoil quickly, lose germination, and cause poor crop stand. Many farmers every year lose good seed simply because it was not dried properly. They are forced to buy new seed from the market, which increases costs.

On the other hand, a farmer who dries seeds properly can store them for months, save money, and ensure healthy crops. Drying is therefore the foundation of seed quality and farmer prosperity.

What is Seed Drying?

Seed drying means reducing the extra water (moisture) present inside seeds to a safe level.

- Freshly harvested seeds often contain 20–30% moisture.
- Safe storage requires moisture of only 6–12%, depending on the crop.

For example, if paddy with 18% moisture is stored directly in bags, it heats up inside, gets fungus, and loses germination. But if it is dried properly to 8–10% moisture, it can be stored for one year without any problem.

Thus, drying is the bridge between harvest and safe storage.

Why Farmers Must Dry Seeds

Farmers must dry seeds before storage for many reasons:

- To maintain germination power.
- To protect from fungi and insects that grow in damp conditions.
- To store safely for long periods until the next season.
- To reduce post-harvest losses and avoid wastage.
- To save money, as dried seeds can be reused instead of buying again.

Drying is not just an extra step – it is the farmers insurance for the next crop.

Safe Moisture Levels for Different Crops

Every crop has a safe moisture limit:

- Paddy, wheat, maize → 8–10%
- Pulses (chickpea, pigeon pea, green gram) → 8–10%
- Oilseeds (groundnut, mustard, sunflower) → 7–8%
- Vegetable seeds (tomato, chilli, brinjal, okra) → 6–8%

If seeds are stored above these levels, they spoil quickly and lose value.

Low-Cost Drying Methods for Farmers

Not all farmers can afford costly machines. But there are simple, low-cost methods:

1. Sun Drying – Spread seeds on mats, tarpaulins, or cement floors. Stir regularly. Protect from sudden rain.
2. Shade Drying – For delicate vegetable and spice seeds. Prevents cracking.
3. Raised Platforms – Bamboo or wooden planks keep seeds away from soil moisture.
4. Solar Tent Dryers – Simple tents made with plastic sheets trap sunlight and protect from dust and birds.
5. Use of Ash or Neem Leaves – After drying, mix seeds with ash, neem, or turmeric to keep away insects.

These methods are cheap, farmer-friendly, and effective.

Problems of Wet Drying

When seeds are not dried properly, farmers face many problems:

- Seeds look dry outside but are still wet inside.
- Heaped seeds generate heat and spoil.
- Fungi like *Aspergillus* grow quickly and damage seeds.
- Insects such as weevils attack damp seeds.
- Oilseeds become rancid and lose their quality.
- Farmers are forced to buy new seed for the next season.

Wet drying is more dangerous than no drying, as it gives a false feeling of safety.

Traditional Methods of Seed Drying

For centuries, farmers have used simple practices:

- Drying seeds in courtyards under the sun.
- Using ash, neem leaves, or turmeric to protect seeds from pests.
- Storing seeds in earthen pots, bamboo baskets, or mud bins.
- Keeping seeds near the kitchen fire to stay dry.

These methods are still useful, especially for small farmers who cannot afford machines.

Modern Methods of Seed Drying

For seed companies and large farmers, scientific methods are used:

- Mechanical Dryers – Use warm air at safe temperature.
- Solar Dryers – Trap sunlight in controlled way, safer than direct exposure.
- Dehumidified Chambers – Provide precise drying for high-quality seeds.

These methods are expensive but necessary for large-scale storage.

Safe Storage After Drying

Drying alone is not enough. Storage must also be proper.

- Use clean cloth bags, plastic bins, or earthen pots.
- Do not mix old and new seeds.
- Keep storage rooms cool, dry, and well-ventilated.
- Add neem leaves, ash, or chilli powder as natural protection.
- Inspect seeds regularly to check for pests or moisture.

Importance of Seed drying

Due to improper drying and storage conditions, seeds suffer from major retarding effects.
These are:
• loss of viability
• discoloration
• toxin production
• growth of fungus.
Therefore, seed conservation through efficient processing and storage becomes factor of prime importance. Proper drying limits the subsequent rate of seed deterioration during long term storage.

Cost Saving and Drying

Drying looks like a small step, but it saves farmers a lot:

- Prevents wastage of good seed.
- Reduces losses from fungi and insects.
- Saves money otherwise spent on buying new seeds.
- Prevents re-sowing costs in case of crop failure.
- Increases market value of seeds.

Example: A farmer who dries paddy correctly can use the same seed for one year, while another farmer who skips drying is forced to buy new seed every season.

Benefits of Proper Seed Drying

- Seeds sprout fast and uniformly.
- Crops grow evenly in the field.
- Plants are healthier and resist diseases better.
- Yields are higher, giving more profit.

Future of Seed Drying

Climate change has increased the need for scientific drying:

- Untimely rains raise seed moisture during harvest.
- High humidity spoils seeds faster.
- Low-cost solar dryers and portable dryers will help small farmers.
- Shared dryers at the village level can reduce costs.
- Future seed banks and food security programs will depend on proper drying.

Seed Drying and Food Security

Seed drying is not only important for one farmer – it is important for the whole nation. Healthy seeds give healthy crops, and healthy crops guarantee food. By practicing proper drying, farmers secure their own harvest and contribute to the food security of the country.

Conclusion

Seed drying may look like a small post-harvest step, but it is the foundation of seed quality. Improper drying brings losses, while proper drying ensures strong seeds, healthy crops, and better yield. Farmers must treat drying as a habit, not just a task. Truly, seed drying is the key to better germination and higher yield.

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WHY BANANA CULTIVATION IS HIGH IN KERALA?

Abstract

Banana cultivation is a significant agricultural activity in the state of Kerala, India, where the crop holds both economic and cultural importance. The state's tropical climate, characterized by warm temperatures and high humidity, along with deep, fertile loamy and lateritic soils, provides an ideal environment for banana growth. Cultivation practices in Kerala vary depending on the season, with rain-fed crops typically planted in April-May and irrigated crops in August-September.

This article explains why banana cultivation is high in Kerala, farmer practices in banana cultivation and traditional farming methods in Kerala, influence of climatic condition in Kerala and the soil and moisture factors, diseases affecting the plant growth, storage practices and exporting of different banana products globally.

Keywords: Banana cultivation, Musa spp. (scientific name), soil and moisture, farmer practices, diseases, storage, traditional methods, exporting

Introduction

Bananas are one of the most widely consumed fruits globally, originating from the tropical regions of Southeast Asia. The plant that produces this fruit, commonly known as the banana tree, is not a true tree but rather a gigantic herbaceous flowering plant of the genus Musa.

The banana plant has a complex and significant role in both agriculture and ecosystems. It is a staple food in many tropical countries and a major export crop. The fruit itself is a rich source of carbohydrates, vitamins, and minerals, particularly potassium. Beyond the fruit, various parts of the plant are utilized: the leaves are used for cooking, serving food, and wrapping; the pseudostem fibers can be made into textiles (e.g., banana silk); and the flower buds are often consumed as a vegetable.

A diverse range of banana varieties are cultivated, each suited to different purposes and regions. Prominent table varieties include Nendran, a staple for both ripe consumption and processing into chips and other products, and Palayankodan (Poovan), which is valued for its sweet and sour flavor. Other notable varieties are Red Banana (Chenkadali), Robusta, and culinary varieties like Monthan. Many of these are integral to local cuisine and religious rituals, highlighting the plant's deep integration into Keralan life.

Banana Cultivation

The banana plant is the world's largest herbaceous flowering plant. Its "trunk" is a pseudostem, and its true stem is an underground structure called a corm. The large, spirally arranged leaves can be several meters long. The plant has an extensive root system that can spread out in loose soil. After the plant produces fruit, the main pseudostem dies. New plants, called "suckers," grow from the corm to replace it. This is why banana plants are often grown in clumps.

Different components of the plant

1. Corm (The True Stem)
2. Pseudostem (The "False Trunk")
3. Leaves
4. Suckers
5. Inflorescence (Banana "Heart")
6. Fruit (The "Bunch," "Hand," and "Finger")

Why banana cultivation is high in Kerala?

Banana cultivation thrives in Kerala due to several factors that make the state particularly suitable for growing this tropical fruit. Here are some of the key reasons:

1. Ideal Climate

- **Tropical Climate**: Kerala has a humid tropical climate, which is perfect for banana cultivation. The temperature ranges from 25°C to 35°C, which is ideal for banana plants, as they require warmth to grow effectively.
- **Monsoon Rains**: The two monsoon seasons in Kerala (southwest and northeast monsoons) provide sufficient rainfall, ensuring that banana plants receive the necessary water to thrive. This also reduces the need for artificial irrigation in many areas.
- **High Humidity**: Bananas need a high level of humidity to grow well, which is common in Kerala due to its geographical location along the Arabian Sea.

2. Fertile Soil

- **Alluvial Soil**: Kerala's soil is rich in nutrients, especially alluvial soil found in the river valleys and coastal areas, which supports healthy growth for banana plants.
- **Loamy Soil**: The state has a large area with loamy, well-draining soil, which is ideal for banana cultivation, as it prevents waterlogging and root diseases.

3. Small Land Holdings & High Demand

- **Small-scale Farming**: Many farmers in Kerala have small land holdings, and banana is a short-duration crop, which allows farmers to grow it even in smaller plots of land. It's also a valuable cash crop that generates quick returns.
- **High Local Demand**: Bananas are an essential part of Kerala's cuisine and culture. They are used in a variety of dishes, snacks, and sweets, which drives demand both locally and in surrounding regions.

4. Variety of Bananas

- Kerala cultivates multiple banana varieties, including Nendran, Robusta, Red Banana, Rasthali, and the common Cavendish. These varieties are used for different purposes, such as raw (for curries), ripe (for eating), and for making products like chips and banana flour.
- **Nendran Banana**: This is a special variety in Kerala, known for its large size and strong flavor, and is highly prized in the local market, especially for making traditional Kerala banana chips.

5. Government Support and Infrastructure

- Kerala's government has provided various incentives and subsidies for agricultural growth, which have included banana cultivation. There are also government-run agencies and cooperatives that help farmers with knowledge, marketing, and resources.
- **Research and Development**: Kerala has invested in agricultural research institutions focusing on improving banana production, pest management, and post-harvest handling techniques.

6. Low Capital Investment

- **Low Initial Investment**: Compared to many other crops, banana farming requires lower capital investment. Banana plants do not require expensive inputs like high-cost machinery, and they also have a relatively short harvest cycle (9-12 months), which makes them economically viable for small farmers.

7. Cultural and Traditional Significance

- Bananas play an important role in Kerala's culture and traditions. They are used in religious rituals, festivals (like Onam), and as offerings in temples. This cultural attachment increases demand and encourages more cultivation.

8. Favorable Terrain

- **Varied Topography**: Kerala's varied topography, from coastal plains to hilly regions, provides diverse environments that are suitable for different varieties of bananas. In addition to lowland areas, highland banana cultivation also occurs in certain parts of the state.

9. Market Access & Export Potential

- **Proximity to Ports**: Kerala has several seaports (like Cochin Port) that facilitate easy export of bananas to international markets, including the Middle East and other countries. The demand for Kerala bananas, especially varieties like Nendran, is high in these regions.
- **Local Markets**: With high local consumption, bananas have a steady demand within the state, helping farmers sustain their income.

10. Efficient Farming Practices

- Over time, Kerala's farmers have developed specialized knowledge in banana cultivation techniques, improving yields and pest management. They also use organic farming practices for growing bananas, which is in line with the state's growing interest in sustainable agriculture.

All of these factors combined make Kerala a banana-producing powerhouse. The state's favorable climate, fertile soils, high demand, and well-developed infrastructure support the success of banana farming. The crop's importance to local culture and cuisine only adds to the long-standing tradition of banana cultivation in the region.

Diseases affecting banana cultivation in Kerala

Banana cultivation in Kerala is affected by several diseases that can severely impact yield and quality. These diseases can be caused by fungi, bacteria, viruses, and pests. Here are some of the major diseases affecting banana cultivation in Kerala:

1. Panama Disease (Fusarium Wilt)
2. Sigatoka Leaf Spot
3. Banana Bunchy Top Virus (BBTV)
4. Bacterial Wilt (Xanthomonas wilt)
5. Cigar End Rot
6. Banana Root Weevil (Cosmopolites sordidus)
7. Root Knot Nematodes (Meloidogyne spp.)
8. Fusarium Leaf Spot
9. Mosaic Disease
10. Anthracnose (Fruit Rot)

Preventive Measures and Integrated Management Practices

- **Sanitation**: Regularly clean tools, remove infected plants, and avoid spreading soil from infected areas.
- **Crop Rotation**: Helps break the cycle of soil-borne diseases like Fusarium wilt and nematode infestations.
- **Resistant Varieties**: Use disease-resistant banana varieties where possible, especially for Fusarium wilt and BBTV.
- **Biological Control**: Use natural predators or biocontrol agents, especially for pests like the banana root weevil.

- **Good Agricultural Practices (GAPs)**: Proper irrigation management, field hygiene, and regular monitoring for pests and diseases can significantly reduce the risk of disease outbreaks.

By taking an integrated approach to disease management and staying vigilant, banana farmers in Kerala can minimize the impact of these diseases and maintain healthy, productive crops.

Products made from banana cultivation

Bananas are incredibly versatile, and nearly every part of the banana plant **from the fruit to the leaves to the stem** can be used to make a variety of products. Here are the major products made from different components of the banana plant:

1. Banana Fruit

- Fresh Bananas
- Banana Chips
- Banana Flour
- Banana Jam
- Banana Ketchup
- Banana Wine
- Banana Vinegar
- Banana Ice Cream
- Banana Cake
- Banana Smoothie or Shake

2. Banana Leaves

- Food Wrapping
- Serving Plates
- Banana Leaf Plates & Bowls
- Craft and Decoration
- Banana Leaf Extracts

3. Banana Stem

- Banana Stem Juice
- Banana Stem Curry
- Banana Stem Fiber.
- Banana Stem Fiber Paper
- Banana Stem Fiber Bags

4. Banana Flower (or Banana Blossom)

- Banana Flower Curry
- Banana Blossom Fritters
- Banana Flower Salad
- Banana Blossom Tea

5. Banana Peels

- Banana Peel Chips
- Banana Peel Powder
- Banana Peel Fertilizer
- Banana Peel Leather

6. Banana Pseudostems (Stem Base)

- Banana Stem Fiber
- Banana Stem Boards
- Banana Stem Rope

7. Banana Seeds

- Banana Seed Oil.
- Banana Seed Powder

8. Banana Sap

- Banana Sap Extracts
- Banana Sap in Traditional Medicine

Conclusion

With the right mix of innovative practices, research investments, and global market access, Kerala's banana cultivation is poised to remain a vital contributor to its economy and culture. The focus on value-added products and export expansion will further elevate Kerala’s position as a leading banana-producing state, both domestically and internationally.

In conclusion, banana cultivation in Kerala has a strong foundation, driven by favorable climatic conditions, cultural relevance, and economic importance. With continued support for sustainable practices and innovation in banana-based products, Kerala has the potential to maintain its leadership in global banana markets.

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Impact of Canal Irrigation on Crop Productivity in Coastal Andhra

Abstract

Canal irrigation has changed farming in Coastal Andhra in a big way. With water from the Krishna and Godavari rivers, farmers are able to grow more crops, achieve better yields, and worry less about uncertain rainfall. This article explains how canals helped farmers increase production, improve incomes, and reduce risks, while also looking at the problems and future solutions.

Introduction

Farming in India depends heavily on water availability. In Coastal Andhra, farmers are fortunate to have an extensive canal system fed by the Krishna and Godavari rivers. These canals act as a lifeline, enabling cultivation beyond the limitations of monsoon rainfall. Previously, farmers had to rely solely on rains, but today, thanks to canal irrigation, they can grow crops during both Kharif and Rabi seasons. This shift has been revolutionary for agriculture in the region and has helped build long-term stability for farming households.

Why Irrigation is Important?

Irrigation plays a vital role in ensuring agricultural stability and food security. The timely supply of water from canals ensures crops receive water when required the most. This leads to stable yields and reduces farmers' dependence on unpredictable monsoons. It also allows multiple cropping, as farmers can grow two or even three crops in a year. This greater productivity improves their income security and enhances the overall agricultural output of the region. Without reliable irrigation, farming would be limited to one season, leaving farmers vulnerable to drought and uncertain rainfall.

Benefits of Canal Irrigation

Canal irrigation has brought several benefits to the farmers of Coastal Andhra. It has led to better yields, with crops such as paddy, sugarcane, and pulses achieving significantly higher productivity. It has enabled multiple cropping, where farmers grow rice in Kharif and pulses or vegetables in Rabi. With assured water supply, farmers have been encouraged to adopt modern farming methods including the use of improved seeds, fertilizers, and agricultural machinery. Farm incomes have risen considerably, providing greater economic stability and creating more employment opportunities. Additionally, seepage from canals has recharged groundwater, benefiting wells and borewells in the region. These combined factors have played a vital role in transforming the agricultural landscape of Andhra Pradesh.

History of Canals in Coastal Andhra

The tradition of irrigation in Coastal Andhra dates back to ancient times when kings and landlords constructed tanks and small canals for paddy cultivation. During the British period, significant developments were made under the guidance of Sir Arthur Cotton, who built the Godavari Anicut (1847–1852) and the Krishna Anicut (1852–1855). These landmark constructions transformed Coastal Andhra into the 'Rice Bowl of Andhra', ensuring large-scale agricultural prosperity. The canals not only expanded agricultural land under cultivation but also supported rural settlements and laid the foundation for the economic growth of the region.

Problems Faced by Farmers

Despite its many benefits, canal irrigation also presents challenges. Waterlogging and soil salinity in certain areas have reduced land productivity. Unequal distribution of water is another major issue, as farmers located at the head-end of canals receive more water than those at the tail-end. Further, significant wastage of water occurs due to seepage, leakage, and inadequate maintenance of canals, undermining the efficiency of the irrigation system. In addition, population growth and increased demand for water have placed additional stress on canal networks, making modernization essential.

Future Solutions

To sustain the benefits of canal irrigation, modern and efficient practices are needed. Farmers and authorities should promote careful and efficient water usage to avoid wastage. Canals should be modernized and lined to minimize leakage and seepage. The conjunctive use of canal water and groundwater can help ensure a more reliable and balanced water supply. Strengthening Water Users' Associations is also necessary so that water distribution can be managed more equitably and effectively at the grassroots level. Encouraging drip irrigation, sprinkler systems, and other micro-irrigation techniques alongside canal irrigation will further increase water-use efficiency and agricultural output.

Impact of Canals: Before vs After

Before Canals	After Canals
Farmers depended only on rains	Farmers receive water throughout the year
Single crop, low yield	Two or three crops, higher yield

Conclusion

Canal irrigation has proven to be a blessing for farmers of Coastal Andhra. It has increased production, reduced risks, and enhanced the standard of living for rural communities. However, to ensure these benefits continue for future generations, both farmers and the government must work together to manage water resources wisely. With proper care and modern management practices, canals will continue to serve as the backbone of farming in Andhra Pradesh. The long-term success of canal irrigation will depend on collective responsibility, modernization of infrastructure, and adaptation to changing environmental and economic conditions.

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HOW FARMERS CAN SAVE MONEY WITH PROPER SEED SAMPLING

Abstract

Seed quality plays a very important role in successful crop production. Many farmers suffer heavy losses due to low germination, poor purity, or seed-borne diseases. Seed sampling is a simple method where a small portion of a seed lot is tested for its quality. It helps farmers to know about germination percentage, moisture level, and health of seeds before sowing. This paper explains the importance of seed sampling, methods of taking correct samples, tools required, challenges faced, and how it helps in saving money by avoiding crop failure, reducing wastage of inputs, and ensuring better yield. Proper seed sampling is a small investment but gives big returns for farmers. Students also believe that promoting seed sampling awareness in villages will help farmers improve income and achieve sustainable farming.

Introduction

Seed is the foundation of agriculture. The success of crop production depends on the quality of seed. If the seed is good, the crop will be good. Many times, farmers face losses even after putting in hard work because the seeds they use are not up to standard. Poor germination, seed mixtures, and diseases carried by seeds result in uneven crop stand and low yield. This wastes money, labour, fertilizer, and irrigation. One simple step to avoid such problems is seed sampling.

Student Idea: As students of agriculture, we feel that seed sampling should be taught in every farmer training program so that no farmer suffers losses just because of poor seed quality.

What is Seed Sampling?

Seed sampling means taking a small portion of seeds from a larger seed lot in such a way that the sample truly represents the entire lot. This sample is then sent to a seed testing laboratory. Testing gives information about germination, purity, moisture content, and seed health. With this knowledge, farmers can decide whether to sow the seed lot, treat it, or replace it.

Importance of Seed Sampling

Seed sampling is very important for farmers because:

- It helps in checking germination percentage.
- It detects seed-borne diseases.
- It identifies unwanted seed mixtures or weed seeds.
- It ensures uniform plant population in the field.
- It saves money by avoiding re-sowing and crop failure.

How Poor Seed Quality Leads to Loss

Low quality seeds can cause huge financial losses. For example, if a farmer buys wheat seeds weighing 100 kg but the germination is only 60 percent, then only 60 seeds out of every 100 will grow. This means 40 percent of land, fertilizer, water, and labour are wasted. The farmer may even have to buy seed again for re-sowing. By testing seeds through sampling, such losses can be avoided easily.

Steps of Proper Seed Sampling

Farmers should follow these steps for correct seed sampling:

1. Mix the seed lot thoroughly before taking samples.
2. Collect small portions from different bags or parts of the seed lot.
3. Combine all portions into one composite sample.
4. Use the quartering method: divide into four equal parts, keep two opposite parts.
5. Repeat until the sample is about 500 g to 1 kg.
6. Pack in a clean bag and send to a seed testing laboratory with crop name, variety, and farmer details.

Methods of Seed Sampling

There are several methods of seed sampling:

- **Manual Method:** Collecting seeds from bags or containers by hand.
- **Quartering Method:** Dividing seed lots into four parts and choosing two opposite parts.
- **Seed Divider Method:** Using mechanical dividers like Boerner or Riffle divider for accuracy.
- **Mechanical Samplers:** Machines used in seed industries for bulk lots.

Tools and Equipment Used

Some important tools used in seed sampling are:

- Seed triers (for taking seeds from bags)
- Boerner divider and Riffle divider (for dividing samples equally)
- Sampling probes and scoops (for large seed lots)
- Clean containers and cloth bags

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Seed Sampling in Different Crops

- **Paddy/Wheat:** Small, light seeds – need samples from many bags.
- **Maize/Groundnut:** Large seeds – fewer seeds are enough for a correct sample.
- **Vegetables (Tomato, Brinjal):** Very tiny seeds – require dividers for accuracy.
- **Pulses:** Medium-sized seeds – must be mixed well before sampling.

Seed Sampling in Small Lots and Large Lots

- **Small Lots (5–10 kg bags):** A handful of seeds from different places is enough.
- **Large Lots (quintals in many bags):** Samples must be taken from every bag for fair representation.

Common Mistakes to Avoid

- Taking seeds only from the top of bags.

- Using dirty or wet bags for samples.
- Sending too little quantity to the lab.
- Not mixing seeds properly before sampling.

Challenges Faced in Sampling

- Lack of awareness among farmers.
- Distance from seed testing labs.
- Cost of equipment for small farmers.
- Lack of trust in reports sometimes.

How Seed Sampling Saves Money

Seed sampling saves money by:

- Avoiding re-sowing
- Saving fertilizer, water, and pesticides
- Reducing labour work
- Preventing seed-borne diseases
- Increasing crop yield and income

Real Life Example

A paddy farmer spends Rs. 5,000 on seeds for one acre. If germination is only 50%, half the crop fails. Re-sowing costs another Rs. 5,000 plus labour and irrigation, making the loss Rs. 12,000–15,000. Testing seeds (cost under Rs. 200) could have saved this loss.

Role of Government and Seed Testing Labs

Government has set up Seed Testing Laboratories across the country. Farmers can send samples at very low fees. Krishi Vigyan Kendras (KVKs) and agriculture universities also help farmers learn about sampling.

Farmer-Friendly Tips

- Always test seeds before sowing.
- Store seeds in cool, dry places.
- Prefer certified seeds.
- Keep a record of test results.

Role of Technology in Seed Sampling

Today, technology can help farmers in seed sampling. Mobile apps, QR codes on seed packets, and online booking of lab tests are already being introduced. Digital reports make it easier for farmers to know results quickly.

From Field to Our Plates

Every meal begins with a seed. Healthy seed ensures healthy crops and food for all. Seed sampling makes this journey safe and successful.

Building Food Security for the Future

The future of farming depends on wise use of resources. Seed sampling reduces waste from the start and builds stronger food security for coming generations.

Conclusion

Seed sampling is a simple but very powerful practice. It saves farmers from losses, reduces wastage, and ensures better yield. **Good seed is half the harvest**. Students believe spreading awareness about seed sampling is a social responsibility because it protects farmers' income and strengthens the nation's food security.

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WHY CANNABIS SATIVA WEED IS MOSTLY PRESENT IN PUNJAB AND HIMACHAL PRADESH AND NOT IN OTHER STATES

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Abstract

Cannabis sativa, known locally as bhang, is spreading fast as a weed in Punjab and Himachal Pradesh. This article explains the why this weed is seen more in these states than in other parts of India. It grows well here because of good climate, fertile soil, and plenty of water. The weed creates many problems for farmers by taking away crop food, water, and space. It reduces the yield of rice, wheat, fruits, and vegetables. The article also discusses traditional and scientific ways to manage the weed, the role of the government, and how farmers can turn this weed into compost or fuel.

Introduction

Weeds are plants that grow where they are not wanted. For farmers, weeds are always a problem because they fight with crops for food, water, and light. Cannabis sativa or bhang has now become a common weed in Punjab and Himachal Pradesh. Long ago it was grown for local use, but now it spreads on its own in fields, bunds, and wastelands. Farmers here face more trouble from this weed than farmers in dry states. This article explains why bhang grows more in Punjab and Himachal, what problems it causes, and how farmers can control it in simple, low-cost ways. The purpose is to help farmers understand clearly and act early to save their crops.

History – How This Weed Came in These Areas

In ancient times, Cannabis sativa, also known as bhang, was grown by people in homesteads and temple gardens for traditional drinks, medicines, and rituals. It was not seen as a problem weed in those days. Over time, due to natural seed dispersal by wind, water, and animals, it spread from cultivated patches to surrounding areas. In Punjab, the construction of canals and irrigation systems in the colonial period created moist bunds and canal banks where the weed grew vigorously. Similarly, in Himachal Pradesh, scattered cultivation and tolerant attitudes allowed the plant to escape into the wild. Today, these plants are mostly unwanted, and farmers recognize them as weeds that compete with crops.

Why It Grows More in Punjab and Himachal

Punjab and Himachal Pradesh have special environmental and social conditions that help Cannabis sativa survive. Punjab has an extensive irrigation network, ensuring continuous water supply. This keeps soils moist, which is ideal for the germination of bhang seeds.

Himachal Pradesh, with its hilly terrain and valleys, provides shaded, moist, and fertile soils. The climate is neither too hot nor too dry, which helps the weed survive the entire season. In both states, due to large areas of uncultivated land along canals, forest edges, and wastelands, the weed spreads quickly. In comparison, other states either do not have such favorable irrigation or climate, or their farming systems are different.

Soil and Weather That Help the Weed

Cannabis sativa is highly adaptable, but it prefers fertile, well-drained loamy soils. These soils are abundant in Punjab's plains and Himachal's valleys. The plant grows best in temperatures between 20°C and 30°C, which are common in both states during kharif and rabi seasons. Monsoon rains provide the moisture needed for quick seed germination. In irrigated zones, even in drier months, the weed continues to survive. This continuous favorable weather makes the weed stronger and more competitive than crops.

Why Other States Do Not Have Much of It

Dry states like Rajasthan and Gujarat face water scarcity and high summer temperatures, often exceeding 40°C. Cannabis sativa cannot withstand such extreme heat and drought. In states with very heavy rainfall and floods, such as Assam and Bihar, the seeds get washed away or waterlogged soils suffocate the seedlings. In some states, strict weed control and awareness campaigns prevent its spread. Thus, the weed finds less chance to multiply outside Punjab and Himachal.

Problems This Weed Gives to Farmers

Cannabis sativa is not just a weed, it is a serious competitor for crops. It competes for nutrients like nitrogen, phosphorus, and potassium. It absorbs soil moisture that crops like wheat, maize, and vegetables need. Its tall height blocks sunlight, making nearby crops pale and weak. Farmers lose significant yield when bhang is left uncontrolled. It also contaminates fodder and stored seeds. The presence of bhang in fields creates legal complications because of its connection with narcotics. Farmers fear inspections and penalties. Thus, it is both an agronomic and social problem.

Impact on Rice and Wheat Fields

In rice fields, bhang grows on bunds and edges. Its roots absorb water meant for paddy, and its shade reduces tiller formation. Farmers have observed a yield reduction of 15–25% when bhang is dense. In wheat fields, the weed grows faster during the early stage, consuming soil nitrogen and reducing grain filling. The wheat crop suffers from weak stems and smaller grains. Overall productivity is badly affected when bhang is left uncontrolled.

Effects on Fruits, Vegetables and Gardens

In orchards, Cannabis sativa grows in the basins of apple, mango, litchi, and citrus trees. It competes for nutrients and moisture, especially affecting young trees. In vegetable fields such as tomato, brinjal, chilli, and cucurbits, it shades the crop, attracts insects, and becomes a hiding spot for pests. Home gardens also get invaded, spoiling their beauty and reducing vegetable harvests. Once it establishes in gardens, it becomes very hard to control.

Traditional Ways Farmers Manage the Weed

Farmers have been fighting this weed with simple methods for decades. Hand weeding with khurpi or hoe after irrigation is effective in small patches. Cutting and burning before seed formation ensures no further spread. Some farmers cover bunds with straw or crop residues to stop weed germination. These methods are cheap but require regular effort and community cooperation.

Scientific Ways to Manage the Weed

Weed scientists recommend integrated approaches. Stale seed bed: Irrigate, allow weeds to sprout, then remove before sowing. Herbicides: Glyphosate and 2,4-D can be used under supervision in non-crop areas, with full safety precautions. Competitive crops: Crops like maize, sorghum, cowpea, and Sudan grass shade out the weed. Hot composting: Collect bhang biomass and compost it at temperatures above 55°C so the seeds die. All these methods together reduce the seed bank in soil over 3–5 years.

Why Dry and Hot States Have Less of It

In dry areas, Cannabis sativa cannot survive due to lack of moisture. High summer heat above 40°C kills seedlings before they establish. Thus, states like Rajasthan, Gujarat, and Haryana's dry zones report very little bhang infestation. This shows that climate and water are the key reasons for its dominance in Punjab and Himachal.

How the Weed Steals from Crops

Bhang roots spread deep and wide, absorbing water that crops need. It takes up fertilizer nutrients before crops can use them. Its tall leaves shade crops, preventing proper photosynthesis. This weakens crops like rice, wheat, and maize, reducing yield and quality.

Why This Weed Grows Faster Than Crops

Cannabis sativa grows faster because of its strong root system and high photosynthesis rate. It can germinate quickly with even small amounts of rain. Its leaves capture more sunlight than crop plants, helping it to grow 1–3 meters tall in a single season. This fast growth gives it a natural advantage over crops.

How This Weed Spreads Quickly in Villages

The weed spreads mainly by seeds. Each female plant produces hundreds of seeds, which survive in soil for many years. Seeds spread with cattle dung, water flow in canals, or by sticking to fodder heaps. When people cut plants and leave flowers on the ground, the seeds still mature and spread further. This is why it moves rapidly from one farm to the entire village.

Role of Government in Weed Control Programme

The government has an important role. It can organize village-level campaigns to uproot the weed before flowering. Departments like Panchayat, Forest, and Irrigation should clear canal banks and wastelands. Awareness programmes must be run to inform farmers of legal risks. Guidelines for safe disposal, composting, and community monitoring should be given. If implemented well, government programmes can greatly reduce the problem.

Turning Weeds into Useful Compost or Fuel

Cannabis sativa can be converted from a problem into a resource. Collected weeds can be placed in compost pits where heat kills seeds and creates rich manure. This compost improves soil fertility and reduces the need for chemical fertilizers. Dried biomass can be used as bio-briquettes or fuel sticks, providing an eco-friendly energy source. Thus, farmers can turn waste into wealth.

Future Farming with Less Weed

If farmers, youth, and government work together for 3–5 years, the seed bank in the soil will decline. Future farmers will face fewer weeds, lower labour costs, and higher yields. Cleaner fields will also mean better quality produce, less tension from legal issues, and more income. Future farming can be more sustainable and peaceful if this weed is controlled today.

Conclusion

Cannabis sativa, though historically valued, has now become a major weed problem in Punjab and Himachal Pradesh. Its growth is favored by good climate, irrigation, and fertile soils. It reduces the yield of rice, wheat, fruits, and vegetables, and spreads rapidly if not controlled. Traditional and scientific methods together can help farmers manage this weed. Community action and government programmes are also essential. If villages work with unity, this weed can be reduced and even turned into a useful resource for compost and fuel. This will ensure a better future for farming and farming families.

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The Role of Nano DAP in Enhancing Crop Productivity and Sustainability

Abstract

Nano DAP (Di-Ammonium Phosphate) is a nanotechnology-based fertiliser developed to improve nutrient use efficiency, reduce dependency on imports, and promote sustainable agriculture in India. Unlike conventional granular fertilisers, Nano DAP comes in liquid form with nanoscale nutrient particles that ensure faster absorption by plants. This article explains the concept of Nano DAP, its production method, how it supports crop growth, and the various government initiatives that encourage its adoption. The information presented highlights how Nano DAP is helping transform Indian agriculture by improving productivity, reducing costs, and contributing to the nation's self-reliance in fertiliser production.

Keywords: Nano DAP, nanotechnology fertiliser, nutrient efficiency, Indian agriculture, Atmanirbhar Bharat

Introduction

Fertilisers play a critical role in sustaining Indian agriculture and ensuring food security. Among them, Di-Ammonium Phosphate (DAP) is one of the most widely used sources of nitrogen and phosphorus. However, India imports over half of its DAP requirement, creating dependency on global markets and leading to a huge financial burden in the form of subsidies. Moreover, conventional DAP is inefficient because only 30–40 percent of the phosphorus is absorbed by crops, while the rest is wasted and often causes soil and water pollution.

To address these challenges, Nano DAP has been introduced. Packaged in small 500 ml bottles capable of replacing a 50 kg bag of granular DAP, it is a highly efficient, environmentally friendly, and farmer-friendly innovation. The Government of India is promoting its large-scale adoption to reduce fertiliser imports, improve crop productivity, and make agriculture sustainable.

What is Nano DAP

Nano DAP is a liquid form of Di-Ammonium Phosphate fertiliser that has been processed using nanotechnology. In this form, nitrogen and phosphorus particles are broken down to a nanoscale size of 20–50 nanometres. Because of this extremely small size, the nutrients can be absorbed directly into plant cells, unlike conventional DAP which takes longer to dissolve and is often lost to the soil before plants can utilise it. Nano DAP contains 8 percent nitrogen and 16 percent phosphorus, making it an efficient and balanced fertiliser that can be applied in small quantities while delivering better results than traditional forms.

Significance of Promoting Nano DAP in India

More Efficient than Conventional DAP

Nano DAP is highly efficient compared to conventional DAP due to its ultrafine particle size, less than 100 nanometres (nm). This allows the fertiliser to easily penetrate the seed surface, stomata, and other plant openings. Improved assimilation of nutrients within the plant system results in higher seed vigour, increased chlorophyll content, enhanced photosynthetic efficiency, better crop quality, and ultimately higher yields.

Cost effective

Nano DAP is cost-effective for both farmers and the government. A 500 ml bottle of Nano DAP, equivalent to a 50-kg bag of conventional DAP, is priced at just Rs 600 compared to Rs 1,350 for a bag of traditional DAP. With government subsidies already in place, using a more affordable fertiliser helps reduce the overall subsidy burden, providing financial relief and promoting wider adoption.

More Convenient for Farmers

Nano DAP is significantly more convenient for farmers as it comes in small 500 ml bottles, making it easier to carry, store, and apply than heavy 50-kg bags. For application, farmers simply mix 250–500 ml of Nano DAP with water and spray it on their crops, with this quantity sufficient for one acre per spray. This reduces labor, simplifies fertiliser management, and makes nutrient application more precise.

Reduction of Import Burden

India currently imports large quantities of conventional fertiliser to meet domestic demand. Promoting domestically-produced Nano DAP, such as that manufactured at the Kalol plant in Gujarat, helps reduce this import dependency. Widespread adoption of Nano DAP will not only improve domestic foodgrain production but also strengthen India's self-reliance in fertiliser manufacturing.

Lesser Impact on Environment

Being in liquid form, Nano DAP has a lower environmental impact than conventional fertilisers. It reduces land contamination and supports healthier soil biology. The use of Nano DAP and liquid urea can also increase earthworm activity, enabling farmers to transition toward natural or organic farming practices without compromising productivity or profitability.

How Nano DAP Helps Crops

- **Wheat and Rice:** Promotes strong root development and better grain filling, resulting in higher yield.
- **Maize and Millets:** Enhances early vigor, chlorophyll synthesis, and overall biomass growth.
- **Vegetables:** Improves leaf colour, flowering, and quality of fruits.
- **Sugarcane and Cotton:** Supports robust plant growth and increases sugar recovery and fibre strength.
- **Pulses and Oilseeds:** Boosts pod setting, seed development, and oil content.

Field trials conducted by IFFCO and agricultural universities across India have shown that crops treated with Nano DAP recorded 8–12% higher yields compared to conventional practices.

Government Initiatives

The Government of India has strongly supported the development and promotion of Nano DAP as part of its larger goal of Atmanirbhar Bharat. Indian fertiliser companies like IFFCO and Coromandel International have been authorized to produce and market Nano DAP. Both companies have developed highly efficient liquid Nano DAP formulations using state-of-the-art nanotechnology to improve crop growth and nutrient use efficiency.

IFFCO Nano DAP

IFFCO Nano DAP is an efficient source of readily available nitrogen (N) and phosphorus, helping to compensate for nutrient deficiencies in crops. The formulation contains 8 percent nitrogen (w/v) and 16 percent phosphorus (w/v), and its particles are smaller than 100 nanometres, providing a high surface area to volume ratio. The ultra-fine nanoparticles can readily enter stomata, exposed surfaces, and other plant openings. By utilizing biopolymers and excipients, the Nano clusters of nitrogen and phosphorus are functionalized to enhance spreadability and systemic digestion throughout the plant. This results in higher seed vigor, greater chlorophyll content, improved photosynthetic efficiency, better crop quality, and increased yields (IFFCO, 2023).

Application of IFFCO Nano DAP

Sr. No.	Method	Application Rate	Water Requirement / Remarks
1	Seed Treatment	3–5 ml per kg of seeds	Mix seeds thoroughly before sowing.
2	Root / Tuber / Sett Treatment	3–5 ml per litre of water	Dip roots, tubers, or setts in solution before planting.
3	Foliar Spray	2–4 ml per litre of water	First spray at tillering/branching stage; second spray at pre-flowering/late tillering stage.
4	Knapsack Sprayers	2–3 caps (50–75 ml) per 15–16 L tank	8–10 tanks are normally required to cover 1 acre of crop area.
5	Boom / Power Sprayers	3–4 caps (75–100 ml) per 20–25 L tank	4–6 tanks are normally required to cover 1 acre of crop area.
6	Drones	250–500 ml per 10–20 L tank	One tank (10–20 L) normally covers 1 acre of crop area.

Application of Coromandel Nano DAP

Pack Size	Dosage per Acre	Number of Sprays	Spray Timing
1 litre	500 ml	Two sprays	First at vegetative stage (4–5 weeks after sowing/transplant), second before flowering stage

Coromandel Nano DAP

Coromandel Nano DAP is a high-end liquid fertiliser developed internally using advanced nanotechnology. It contains nanoparticles of DAP with 2 percent nitrogen (N) and 5 percent phosphorus pentoxide (P2O5) w/v. The small particle size and expansive surface area allow it to be readily absorbed by plant leaves and enable systemic absorption throughout the plant. The Nano-formulation promotes enhanced crop.

Environmental Benefits of Nano DAP

Nano DAP offers multiple environmental and agronomic advantages. Its ultrafine particles increase the surface area, enabling enhanced nutrient absorption, which results in robust plant growth and higher yields. Unlike conventional fertilisers, Nano DAP reduces nutrient runoff and groundwater contamination, making it an eco-friendly option. It is also cost-efficient, minimizes fertilizer wastage, and supports sustainable agriculture by reducing chemical fertilizer dependency and encouraging responsible nutrient management.

- **Environmental Friendliness:** Reduces groundwater contamination and soil nutrient imbalance.

- **Cost Efficiency:** Minimizes fertilizer wastage, lowers input costs, and improves financial returns for farmers.

- **Sustainable Agriculture:** Promotes responsible nutrient management and reduces chemical fertilizer dependency.

Challenges in Adoption

Despite its many benefits, the adoption of Nano DAP faces several challenges:

- **Limited Awareness:** Many farmers are unaware of the benefits and correct usage of Nano DAP.

- **Higher Initial Cost:** The price per bottle is higher than conventional DAP, which may discourage small-scale farmers.

- **Technical Knowledge Required:** Proper application methods such as foliar spraying, seed treatment, and drone spraying require training.
- **Supply Chain Constraints:** Availability may be limited in remote rural areas, affecting widespread adoption.
- **Resistance to Change:** Traditional farmers often prefer granular fertilisers due to familiarity, reducing willingness to adopt new technology.

Conclusion

Nano DAP represents a breakthrough in fertiliser technology that directly supports India's agricultural needs. By improving nutrient efficiency, reducing fertiliser dependency, and saving subsidy costs, it has the potential to reshape farming practices. Its easy application methods, better crop response, and environmental advantages make it a farmer-friendly and eco-friendly solution. With continued government support and farmer participation, Nano DAP is expected to play a major role in building a sustainable and self-reliant agricultural future for India.

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AUTOMATION AND ROBOTICS IN ADVANCED VEGETABLE HARVESTING AND POST-HARVEST HANDLING

Introduction

The global demand for fresh vegetables is increasing rapidly, driven by population growth, urbanization, and rising health awareness. This surge places significant pressure on agricultural systems to enhance productivity, efficiency, and sustainability. Traditional vegetable harvesting and post-harvest handling methods are labour-intensive, time-consuming, and often inefficient, resulting in crop losses and quality degradation. Automation and robotics present transformative solutions to these challenges by improving precision, reducing labour dependency, and ensuring better product quality throughout the supply chain.

Automation and Robotics in Vegetable Harvesting

1. Precision Harvesting Robots

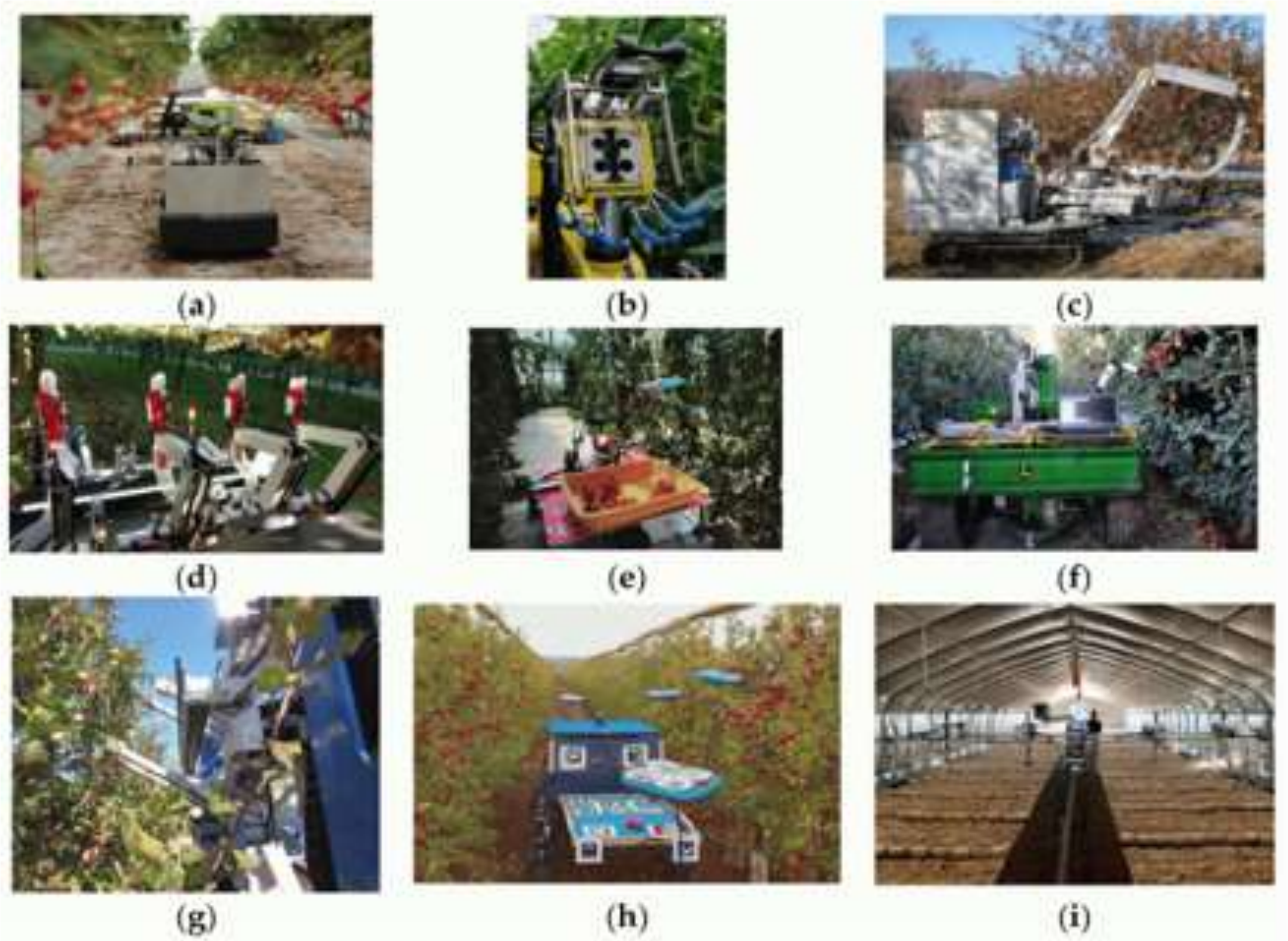
Advanced harvesting robots are designed to selectively identify and pick vegetables based on ripeness, size, and quality. Utilizing technologies like computer vision, machine learning, and AI, these robots can distinguish ripe produce from unripe or damaged items. For example, robotic arms equipped with cameras and sensors navigate the crop rows, delicately pluck vegetables such as tomatoes, peppers, cucumbers, and leafy greens without damaging the plants.

Advantages Over Manual Harvesting

Increased Efficiency: Robots can operate continuously, accelerating harvesting speed and reducing time to market.
Labor Shortage Solution: Many regions face a shortage of skilled agricultural labor, and robots help bridge this gap.
Consistent Quality: Automated systems reduce human error and maintain uniform harvesting standards.
Reduced Crop Damage: Gentle handling by robotic systems decreases bruising and waste.

Examples of Robotic Harvesters

Tomato Harvesters: Robots use multispectral imaging to detect ripe tomatoes and robotic grippers to pick them efficiently.
Leafy Greens Harvesters: Machines equipped with laser scanners cut leafy vegetables with precision, minimizing waste.
Root Vegetable Harvesters: Automated systems carefully dig, lift, and sort root crops like carrots and potatoes.



2. Automation in Post-Harvest Handling

Once harvested, vegetables undergo several post-harvest processes such as cleaning, sorting, grading, packaging, and storage. Automation enhances these stages by increasing throughput and maintaining quality.

Automated Sorting and Grading
Robotic vision systems assess vegetable size, shape, color, and defects to sort and grade produce rapidly and accurately. Sorting belts equipped with sensors can reject substandard items, ensuring only premium quality vegetables proceed to packaging.

Intelligent Packaging Systems
Robotic packaging lines can automatically arrange vegetables into trays or boxes, seal them, and label packages. Customizable packaging solutions extend shelf life by controlling atmosphere conditions such as humidity and temperature.

Automated Storage and Cold Chain Management
Automated storage solutions use robotic shuttles and climate-controlled warehouses to optimize space and maintain freshness. IoT sensors monitor temperature humidity in real-time, alerting operators to any deviations that might spoil produce.

Benefits of Automation and Robotics in Vegetable Supply Chains
Reduction of Post-Harvest Losses: Automated handling minimizes mechanical damage and contamination.
Improved Traceability: Integrated systems provide detailed tracking from farm to fork.
Sustainability: Reduced waste and energy-efficient handling processes lower the environmental footprint.
Cost Efficiency: Though initial investments are high, long-term savings from reduced labor costs and losses justify adoption.

Challenges and Future Prospects
Despite the advantages, challenges remain in widespread adoption.
High Capital Investment: Small-scale farmers may find robotic systems cost-prohibitive.
Complexity of Crops: Diverse shapes, sizes, and growth patterns of vegetables demand highly adaptable robots.
Technical Expertise: Maintenance and programming require specialized skills.

Integration with AI and Machine Learning: Advanced AI will enable predictive analytics for better crop management and supply chain optimization.

Autonomous Multi-Task Robots: Future robots may perform multiple functions — harvesting, sorting, packing — seamlessly.

Enhanced Soft Robotics: Further development of soft, flexible robotic technologies will allow safer handling of even the most delicate vegetables.

Swarm Robotics: Groups of smaller robots working collaboratively to cover large fields efficiently.

Remote and Cloud-Controlled Operations: Farmers will be abl.e to monitor and control harvesting and post-harvest processes remotely via smart devices.

Customization for Diverse Crops: Robotics tailored to different vegetable types and farming conditions worldwide.

Future developments in AI, sensor technology, and materials science promise more versatile, affordable, and user-friendly solutions. Collaborative robotics (cobots) working alongside humans could bridge gaps in flexibility and cost.

Conclusion

Automation and robotics are revolutionizing vegetable harvesting and post-harvest handling, addressing labour shortages, reducing losses, and enhancing quality. While challenges remain, ongoing innovation and decreasing costs suggest a future where these technologies become standard tools in sustainable vegetable production systems worldwide.

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Sustainable Alternatives to Plastics in Food Packaging

Introduction

Plastics are used everywhere in modern life, especially in food packaging. They are cheap, light, and easy to produce. Because of these qualities, plastics became the most common choice for wrapping, storing, and transporting food. But plastics have one big problem—they do not break down easily. A single plastic bag or food container can last for hundreds of years in the environment. This slow breakdown has led to serious problems. Plastic waste piles up in landfills, pollutes rivers and oceans, and even enters our food through tiny pieces called microplastics. These issues have created a global crisis. Every year, millions of tons of plastic are produced, and a large part of it is used only once before being thrown away. To solve this problem, researchers are searching for new, safer materials. One promising solution comes from agriculture. Farming produces a huge amount of waste every year—rice husks, corn cobs, wheat straw, banana peels, sugarcane bagasse, and more. Instead of being burned or dumped, these materials can be turned into biopolymers. Biopolymers are natural, biodegradable materials that can be used to make packaging. This article explains how agricultural waste can be used for food packaging. It looks at the kinds of materials we can get from farm waste, the benefits of using them, the challenges we face, and how they could replace plastics in the future.

Agricultural Waste as a Resource

When farmers harvest crops, a lot of leftovers remain. Rice husks cover each grain of rice, corn cobs remain after kernels are removed, and sugarcane bagasse is left after juice is taken out. Fruit processing creates tons of peels, and dairy production leaves behind whey. Most of this material has little value. In many places, farmers burn crop residues to clear land quickly. This practice creates smoke and releases harmful gases into the air. If not burned, the waste often ends up rotting in piles, releasing greenhouse gases like methane. But this so-called 'waste' is full of useful ingredients. Agricultural residues contain cellulose, starch, proteins, and fibers, all of which can be used to make new materials. Instead of causing pollution, these leftovers can become raw materials for biodegradable packaging.

Using agricultural waste has another benefit: it does not require new farmland or extra fertilizer. It makes use of what is already there, turning low-value byproducts into high-value products. This creates extra income for farmers and supports rural communities.

Types of Biopolymers from Agricultural Waste

1. Cellulose-Based Packaging

Cellulose is found in the walls of all plants. Rice husks, wheat straw, and corn stalks are full of it. From these wastes, cellulose can be extracted and turned into thin films. These films are strong, clear, and biodegradable. However, they absorb water easily, so scientists are finding ways to make them more water-resistant by blending them with other natural materials.

2. Starch-Based Packaging

Starch is found in crops like corn, cassava, potatoes, and even banana peels. Starch can be made into flexible packaging films. These films break down naturally and are safe for food use. Their weakness is that they can tear easily and absorb moisture. To fix this, starch is often mixed with other fibers or reinforced with natural additives. Today, many biodegradable bags and trays are already made using starch.

3. Protein-Based Packaging

Agricultural and food industries leave behind protein-rich byproducts, such as soy waste, wheat gluten, and whey from milk processing. These proteins can form thin films that act as good barriers against oxygen, helping food stay fresh. However, they do not resist moisture well and need extra treatment. Some researchers are adding antimicrobial agents to protein films, which means they can also protect food from bacteria.

4. Microbial Bioplastics (PLA and PHA)

Some agricultural residues, like fruit peels and sugarcane bagasse, are rich in sugars. Microorganisms can feed on these sugars and produce PLA (polylactic acid) and PHA (polyhydroxyalkanoates). These are biodegradable plastics that look and behave like regular plastics. They are already being used in cups, containers, and other packaging. The main issue is that they cost more to produce compared to petroleum plastics, but new research is making them cheaper each year.

Benefits of Using Agricultural Waste

Using agricultural waste for food packaging has many advantages:

1. Reduces pollution: Instead of burning or dumping residues, they are turned into useful products.
2. Eco-friendly: Biodegradable packaging breaks down naturally without leaving harmful traces.
3. Supports farmers: Farmers can sell crop residues, earning extra income.
4. Saves resources: No new land, fertilizer, or water is needed—waste is reused.
5. Food safety: Most biopolymers are safe, non-toxic, and suitable for food contact.

Challenges

Even though the idea is exciting, there are still challenges:

- Weaker materials: Some biopolymers are not as strong or water-resistant as plastic.
- High cost: Biodegradable packaging usually costs more to produce.
- Complex processing: Extraction and treatment of residues can be complicated.
- Strict regulations: Packaging must meet food safety rules before it can be used.

These issues mean more research and investment are needed before agricultural waste packaging can fully replace plastic on a large scale.

Future Opportunities

The future looks promising. Researchers are working on:

* Better methods to extract useful compounds from waste with less energy.
* Mixing materials to make stronger and more flexible films.

* Adding antimicrobial properties to keep packaged food fresh longer.
* Cheaper production by improving fermentation and scaling up factories.
* Government support such as banning single-use plastics and giving incentives for green packaging.

With these improvements, packaging made from agricultural waste could soon become common in markets and restaurants.

Conclusion

Plastic pollution is one of the biggest environmental problems today. Agricultural waste offers a smart and sustainable solution. By turning rice husks, corn cobs, fruit peels, and other residues into biodegradable packaging, we can reduce waste, protect the environment, and give farmers new opportunities.

While there are still challenges like cost and performance, the benefits are clear. With more innovation and strong support from governments and industries, agricultural waste-derived packaging could replace plastics in many areas. This approach not only helps the planet but also builds a circular economy—where waste is not thrown away but reused to create valuable new products. Agricultural waste biopolymers show us that a cleaner, greener future is possible if we make the right choices today.

Reference

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The Tobacco Industry In Rajahmundry : Legacy, Innovation, and Transition

Abstract

Rajahmundry, a historic city in Andhra Pradesh, plays a pivotal role in the Indian tobacco industry. It is home to the Central Tobacco Research Institute (CTRI), now known as the ICAR-National Institute for Research on Commercial Agriculture (NIRCA). The city has long been a hub for tobacco cultivation, research, and exports. This article highlights the legacy of the tobacco industry in Rajahmundry, its socio-economic importance, recent technological advancements, challenges such as overproduction and illegal trade, and its gradual shift toward sustainable and diversified agriculture.

Introduction

Rajahmundry hosts the CTRI, a premier research institution that has shaped tobacco cultivation methods and quality across India. To promote collaboration, the Tobacco Research Workers Association was formed in 1973 and registered in 1974. In line with changing global health concerns and agricultural priorities, CTRI was renamed ICAR-NIRCA, marking the region's transition from tobacco dominance to a broader focus on commercial crops. Rajahmundry today represents an important case study in balancing agricultural heritage with modern sustainability.

Establishment of CTRI

Founded in 1947 and brought under ICAR the same year, CTRI has been at the forefront of tobacco research. It developed dozens of tobacco varieties suited for diverse agro-climatic regions, significantly boosting productivity and farmer income.

Transition to NIRCA

Reflecting a broader policy shift, CTRI was restructured into ICAR-NIRCA with a mandate to include commercial crops such as turmeric, chilli, castor, and ashwagandha. This transition underscores India’s efforts to reduce dependence on tobacco and promote diversified agriculture.

Why Rajahmundry?

The fertile black soils of Krishna and Guntur districts made Rajahmundry ideal for tobacco. Popular varieties such as Gowtami, Hema, and VT1158 thrive here. Crops are usually planted between October and November and harvested from December to February. With yields up to 1650 kg/ha, this region became a major export hub for countries in CIS, Eastern Europe, West Asia, North Africa, and Japan.

Fall of the Tobacco Industry

Tobacco consumption globally declined from 1.32 billion users in 2015 to 1.30 billion in 2020, according to the World Health Organization (WHO). During the COVID-19 pandemic, tobacco faced greater stigma due to health risks. Price collapses in Andhra Pradesh further strained farmers, forcing government interventions and stricter production regulations.

Surge in Export Potential (2024)

Despite setbacks, 2024 witnessed a revival. Andhra Pradesh saw auction prices rise from Rs.225/kg to Rs.286.57/kg. Exports surged by 35% in one quarter, reaching Rs.426 million, and grew 19% for the financial year, restoring some confidence among farmers and traders.

Economic and Social Importance

The tobacco industry sustains over 45 million livelihoods in India. In Andhra Pradesh, thousands of farmers and laborers depend on it directly. Tobacco exports generate around Rs.6,000 crore annually, with Rajahmundry playing a significant role.

Innovation and Technology

NIRCA provides over 90% of India’s tobacco seed stock and maintains a vast germplasm bank. A notable achievement is the LPG-based tobacco curing technology, developed with Indian Oil Corporation. This method reduces emissions, costs, and curing time compared to traditional firewood methods.

Challenges

The industry faces recurring issues such as overproduction, tenant farmer distress due to price crashes, and the rise of illegal tobacco trade including gutka and khaini. These challenges threaten both farmer livelihoods and public health.

Sustainable Shifts and Future Outlook

NIRCA now emphasizes alternative crops and value-added agriculture. The Andhra Pradesh government has stepped in with support measures, including procurement centers for small farmers. Meanwhile, stricter regulations are being enforced against illegal tobacco products.

Crop Size Reduction

The Indian Tobacco Board has reduced Andhra

Pradesh's crop size for 2025-26 by 18%, fixing it at 142 million kgs, down from 167 million kgs the previous year. This decision reflects ongoing market pressures and efforts to stabilize prices.

Rise of the Tobacco Industry

The growth of Rajahmundry's tobacco sector is closely tied to CTRI/NIRCA, whose research improved productivity, exports, and farmer incomes. Over the years, the institute also diversified into research on other commercial crops, broadening its impact.

Conclusion

Rajahmundry's tobacco story is one of transformation. Once a global tobacco hub, it now symbolizes India's push towards agricultural diversification and sustainability. While the industry continues to support millions, innovation, regulation, and alternative crops will define its future. The rebranding of CTRI as NIRCA marks a significant step toward a more sustainable and health-conscious agricultural economy.

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Sustainable Packaging of Fruits and Vegetables in Indian Supermarkets: Lessons from Thailand's Banana-Leaf Innovation

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Abstract

A key tactic to reduce the environmental effect of the extensive use of plastic in fresh produce markets is sustainable packaging, which is quickly becoming popular. Indian supermarkets are under pressure to switch from plastic to eco-friendly packaging due to stringent government rules and growing customer awareness. Given its scalability and cultural compatibility, Thailand's effective use of banana-leaf packing provides an example that is worth examining in the Indian setting. The packaging issue in Indian supermarkets is examined, the viability of copying Thailand's banana-leaf innovation is looked into, and the effects of employing conventional and alternative materials on the economy and ecology are assessed. A strategic framework for incorporating reasonably priced, culturally relevant, and biodegradable fruit and vegetable packaging solutions into Indian retail ecosystems is presented in this article. Comparative experiences from throughout the world, especially in Southeast Asia, serve as its foundation.

1. Introduction

India is one of the world's largest producers and consumers of fruits and vegetables, with an annual production of about 320 million metric tons (FAO, 2022). Fresh produce packaging has become crucial to supply chain efficiency and consumer convenience as urbanization and modern retail networks have expanded. However, the use of single-use plastic packaging is becoming a more significant environmental issue. Food packaging accounts for a significant portion of India's annual production of 3.5 million metric tons of plastic waste (CPCB, 2021). Thailand, a neighbor of Southeast Asia with a similar climate and culture, gained international notice when it started using banana leaves instead of plastic to package fruit in supermarkets (UNEP, 2019). This review evaluates the model's applicability to the Indian context, focusing on its sustainability, scalability, and socioeconomic impacts. Supermarkets all across the globe utilize plastic packaging for fresh produce because it minimizes handling damage, increases apparent shelf life, and makes marketing easier. However, growing legal pressure to restrict single-use plastics and mounting evidence of environmental impact from plastic pollution have sparked interest in biodegradable, locally produced, and circular alternatives. A well-known example from Thailand in 2019—where a grocery chain started wrapping vegetables with banana leaves instead of plastic—was extensively reported in the world press and sparked similar experiments in nearby nations. This concept is noteworthy since banana leaves are naturally biodegradable, plentiful locally in many tropical places, and culturally recognizable as food wrap.

Though it presents concerns about food safety, uniformity, scalability, and transferability to other retail environments like Indian supermarkets, the Thai model has promise.

2. The Packaging Methods Used in Indian Supermarkets Today

2.1 The Environmental Impact and Dominance of Plastic

Plastic is still the most often used packaging material in Indian retailers since it is cheap, durable, and easy to use. Commonly utilized materials include polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET). Despite their usefulness, these polymers are not biodegradable and may worsen soil and water contamination if improperly disposed of. About 60% of fruits and vegetables are sold on plastic trays or wrapped in plastic in Indian urban markets. On a nationwide scale, this usage results in the production of thousands of tons of plastic waste every year.

2.2 Consumer Trends and Preferences

The increase in eco-labeling and biodegradable packaging indicates that urban Indian customers are becoming more interested in sustainable practices. However, cost sensitivity and perceived sanitary attributes often affect plastic packaging decisions. Consumer acceptability is presumably strong in many sectors as banana leaves are a traditional serving/wrapping media in many Southeast Asian and Indian cuisines. Positive customer response and social media acclaim were emphasized in Thai media stories. Supermarkets must, however, determine if consumers believe that fruit wrapped in leaves is sanitary and suitable for contemporary retail settings (such as chilled, plastic-free produce sections). Hesitancy may be reduced with clear labeling that identifies cleanliness and pesticide testing.

3. The Innovation of Thailand's Banana Leaf: A Sustainable Substitute

3.1 Origin and Performance

Fruits and vegetables were first wrapped in banana leaves and bound together with organic bamboo fibers at Thailand's Chiang Mai's Rimping Supermarket (UNEP, 2019). This concept gained worldwide attention since it was both aesthetically pleasing and environmentally friendly. When pictures of vegetables wrapped in banana leaves went viral online in 2019, Rimping Supermarket in Chiang Mai attracted interest from all around the world. According to many media publications, the company replaced plastic wraps with locally obtained, often discarded banana leaves to bundle products like veggies and herbs. The activity was promoted as a low-cost, locally relevant initiative that made use of both consumer familiarity and an abundance of biomass. Other stores in Vietnam and the surrounding area expressed interest in experimenting with similar strategies as a result of the campaign's viral prominence. Three main factors contributed to the Thai pilot's appeal: (a) visibility and ease of use—no new polymer chemistry was needed; (b) environmental narrative—less plastic was seen as good public relations; and (c) cultural fit—banana leaves are a common food wrap in the area. However, supply logistics, cleanliness practices, and lifecycle trade-offs—all of which are essential for transferability—were often not thoroughly examined in media accounts.

3.2 Material Advantages

Banana leaves are abundant, naturally antimicrobial, biodegradable, and water-resistant (Sundari et al., 2020). They are abundantly available and culturally acceptable due to their usage in traditional Thai cuisine and rituals. Studies have shown that banana leaves, as opposed to plastic, extend the shelf life of food by one to two days due to their porous nature. There is little empirical evidence about the shelf life of goods covered in banana leaves. Although findings vary by species, processing technique, and product type, several research on leaf-based packing sheets indicate good barrier characteristics to water vapor and bacteria when processed into composite materials. Fresh banana leaves' natural resistance to water may temporarily shield fragile fruit from abrasion and moisture loss, but untreated leaves are vulnerable to mechanical deterioration and microbiological colonization. Therefore, processing (drying, mild heat treatment, or shaping into stable sheets) is probably required for longer supply chains or pre-packaged, refrigerated retail displays. When switching to plant-based wraps, food contact regulations and safety are crucial. Field-collected fresh leaves may include microbiological pollutants, pesticide residues, or dirt. Risks may be reduced by using processing techniques that disinfect leaves, such as washing, blanching, controlled drying, or coating with food-grade, biodegradable barriers; however, these techniques need to be approved by regional regulatory bodies. Any leaf-based solution must comply with food safety migration testing and traceability standards, since the Indian regulatory agencies (FSSAI) have been revising packaging guidelines to take recycled and innovative materials into consideration.

3.3 The Effect on the Economy and Environment

In Thailand, the cost of packing banana leaves is similar to that of plastic since they are readily accessible locally and are encouraged by the government. A lifecycle analysis conducted by Phongphiphat et al. (2021) found that banana leaf packaging might reduce carbon emissions by up to 65% when compared to PET.

4. India and Thailand's Comparative Agro-Climatic Potential

Similar agroclimatic zones may be found in Thailand and India, particularly in the south and northeast where bananas are farmed in significant numbers. India is the world's largest producer of bananas, producing around 30 million metric tons year (FAOSTAT, 2022). This surplus serves as a sustainable feedstock for leaf-based packaging. However, logistical, preservation, and infrastructural problems need to be solved to ensure broad adoption.

5. Logistical and Technological Difficulties in India's Adoption of Banana Leaf Packaging

5.1 Sturdiness and Preservation

The dry, hot heat that is typical throughout much of India makes banana leaves even more perishable. If they are not refrigerated, their shelf life is just two to three days. However, pre-treatment techniques like glycerol-based lamination or starch coating may increase shelf life.

5.2 Infrastructure of the Supply Chain

India's supply chain for banana leaves is not as well-organized as Thailand's. It is necessary to provide facilities for collecting, transporting, and storing. Facilities for leaf drying, grading, and sanitization would be required to ensure food safety regulations.

6. Indian Farmers and Retailers' Economic Viability

In India, banana leaves now fetch low market prices despite being primarily used for composting, temple construction, and traditional culinary services. The growing popularity of packaging might open up a new cash stream for banana growers. If banana leaves were sold for packaging, farmers might earn an additional ₹1.5–2 per leaf, increasing the annual value of banana plants by ₹15,000–20,000 per hectare. Retailers would benefit from consumer goodwill, increased brand awareness, and compliance with government plastic bans.

7. India's Regulatory and Policy Environment

India's "Plastic Waste Management Rules, 2016" (which were updated in 2022) prohibit some forms of single-use plastic. States like Sikkim, Tamil Nadu, and Maharashtra have taken strong action to enforce plastic bans in retail (MoEFCC, 2022). Despite these regulations, there are currently little incentives for alternative alternatives and a lack of enforcement. Government subsidies, public-private partnerships, and GST exemptions for eco-friendly packaging might all contribute to closing the gap. Surveys show that more than 68% of Indian consumers in cities are willing to pay an extra 10% for packaging that is more ecologically friendly. However, awareness levels in tier-2 and tier-3 cities remain low. Customers must be educated via labeling, advertising, and in-store incentives in order to alter the dynamics of demand.

9. Case Studies of Indian Banana Leaf Packaging

9.1 Tamil Nadu: Customary Use Performed in Contemporary Stores

Organic merchants in Tamil Nadu have started using banana leaf wrapping a lot, especially in the farmers' markets in the state. Even though the practice is in accordance with cultural standards, large shop chains have yet to implement it.

9.2 Kerala: In Kerala and parts of Karnataka, banana leaf trays are utilized for room service and display packing in tourist and retail facilities. Although these efforts are commendable, they are nonetheless scattered and restricted.

10. The Strategic Adoption Framework for Indian Supermarkets

10.1 Farmer-Sourcing Relationships

Provide training in sustainable leaf extraction and preservation; establish farmer cooperatives for banana leaf harvesting; and collaborate with FPOs and Krishi Vigyan Kendras (KVKs).

10.2 Infrastructure and R&D

Locate leaf conditioning machines near

banana-growing clusters, develop hybrid packaging (leaf + jute/bioplastic) for strength and moisture control, and work with research institutions to increase shelf life.

10.3 Rewards for Retailers

Retailer education on banana leaf handling and cleanliness; • Green certification programs; • Tax incentives and recognition for sustainable projects

10.4 Customer interaction:

Eco-labeling, green tags, and "packaging score" on invoices; in-store information desks; and loyalty benefits for selecting eco-friendly packaging

11. Regulatory and policy environment in India

India has advanced efforts to decrease single-use plastics and greatly strengthened plastic waste management regulations (the Single-use Plastic (Regulation) Act and Plastic Waste Management Rules). Extended producer responsibility (EPR), traceability, and regulations for recovered plastics and environmentally appropriate substitutes are the main topics of more recent notices and modifications (2024–2025). Concurrently, new packaging regulations issued by the Food Safety and Standards Authority of India (FSSAI) permit the use of certain recycled materials in food contact applications provided they pass certain safety testing. Both incentives and limitations are produced by these regulatory changes: they promote alternatives but demand that all new materials undergo stringent food-contact safety testing and traceability. Coordination with FSSAI guidelines and state/local municipal composting facilities would be crucial for supermarkets to employ banana-leaf packaging.

12. Lessons from Thailand for Indian supermarkets — transferable insights and caveats

From the Thai experience and the supporting literature we distill actionable lessons:

- Start small with pilot stores: Thailand's first noticeable pilot was a low-cost trial that was inspired by a local brand. Before a nationwide deployment, Indian supermarkets, particularly regional chains, should conduct controlled pilots in locations close to banana producing regions to gauge customer reaction and logistics.
- Give hygiene procedures first priority: gathering leaves from farms is insufficient. Put in place washing, sanitizing, and traceability procedures, and confirm with FSSAI-aligned testing for microbial contamination and pesticide residues. For the sake of customer confidence and legal compliance, these procedures must be documented.
- Take into account processing for shelf stability: Invest in mild processing (such as blanching, drying, or creating sheets) to stable leaves for a longer shelf life or for centralized distribution. Labeling, printing, and automated handling may all be made possible by processing. Studies on processed banana leaf sheets indicate that there are workable solutions, but they need industrial optimization.

- Design for local circularity: Make sure that end-of-life pathways—such as farmer return streams, composting, and municipal organic waste systems—are established to ensure that leaves are composted instead being dumped in landfills. Environmental results will be enhanced by collaborations with nearby governments or composting service providers.
- Make explicit communication with customers: Labeling that clarifies the product's origin, cleansing, and disposal (for example, "compostable — return to organics bin") helps allay hygienic worries and develop uplifting brand narratives. Publicity via social media, as in Thailand, may increase effect, but it has to be supported by sound procedures.
- Evaluate scale and economics: Compare the existing plastic costs plus externalities and expenses associated with regulatory compliance by doing a bottom-up costing exercise that considers the collecting, processing, staff time, and merchandising effect of leaves. When feasible, include LCA.
- Involve regulators from the outset: To make sure the strategy satisfies food safety and traceability regulations and that disposal routes are identified, early consultation with the FSSAI and municipal waste authorities is recommended. India's recent legislative changes demonstrate a willingness to accept recycled and alternative packaging, but they still need for traceability and demonstrated safety.

13. Limitations

There is a dearth of comprehensive empirical data on cleanliness, prices, and lifecycle implications in the Thai supermarket instance, and the majority of the available material is from journalistic sources. There is a small body of peer-reviewed research on processed banana leaf materials, most of which are lab-scale or proof-of-concept studies. Strong conclusions on scalability throughout the country should thus be cautious and stress the need of pilots and verified testing.

Conclusion

Thailand's creation of the banana leaf is a compelling example of ecologically beneficial fruit and vegetable packaging. India is well positioned to replicate and extend such models because to its massive banana production, cultural affinity, and rising environmental consciousness. Nonetheless, success requires coordinated efforts from the retail, R&D, policy, and agriculture sectors. By using biodegradable packaging made of banana leaves or a similar material, India may drastically reduce its plastic footprint in the fresh fruit industry. If Indian supermarkets have the backing of their consumers, governmental support, and creative business strategies, they might set the standard for environmentally friendly packaging and become a global model. In many regions of India, banana-leaf packaging is a visually appealing, culturally appropriate, and locally accessible substitute for single-use plastic wrapping for fresh products. The example of the Thai shop shows how popular the idea is and how feasible it is on a local scale. Food safety validation, processing to increase shelf life and allow for standardized handling, supply-chain planning to align leaf availability with distribution networks, compatible municipal composting infrastructure, and an evidence base derived from pilot trials and lifecycle assessments are all necessary for widespread adoption in Indian supermarkets. Banana-leaf and other leaf-based packaging could be incorporated into India's shift to sustainable supermarket packaging with the correct institutional support. Policymakers, retailers, researchers, and farmer groups should work together to develop pilot programs that document hygiene protocols, economic costs, and environmental benefits.

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MOLECULAR APPROACHES FOR GENETIC IMPROVEMENT OF VEGETABLE CROPS

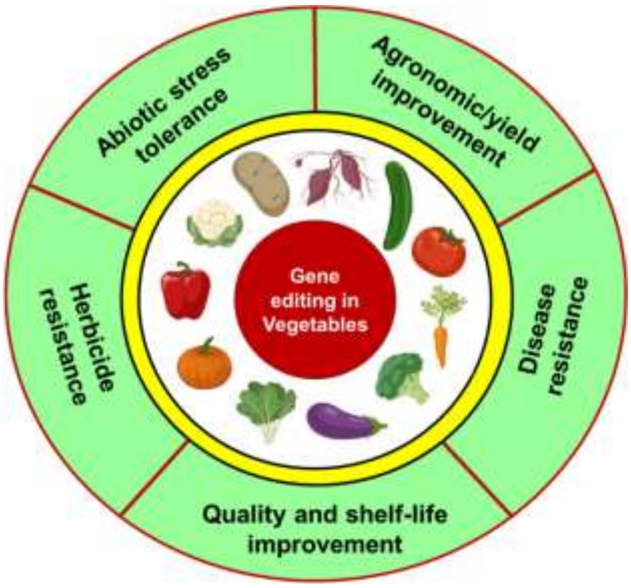
Abstract

Vegetable crops are crucial for food security and economic growth, especially in countries like India, where diverse agroclimatic conditions support the development of a wide range of species. Conventional breeding has contributed significantly to improving yields and quality, but is often time-consuming and limited by environmental factors. Molecular approaches, including molecular markers, marker-assisted selection (MAS), genomic tools, genetic engineering, and genome editing, have revolutionized vegetable crop improvement, enabling the precise and rapid development of improved varieties. In India, these tools have been successfully applied to crops such as tomatoes, eggplants, cucumbers, and chili peppers to improve traits such as disease resistance, yield, and nutritional quality. Combining molecular breeding with conventional methods holds great promise for solving future challenges in vegetable production, ensuring sustainable growth and resilience to climate change.

Keywords: Food security, Genetic engineering, Molecular breeding, Vegetable crops, Marker-assisted selection

1. Introduction

Vegetable crops play a crucial role in our diet, offering important vitamins, minerals, and antioxidants. In India, staples like tomatoes, brinjals, okra, cabbage, and cauliflower are not only vital for nutrition but are also key to the livelihoods of farmers.



Yet, traditional breeding methods can take years to develop better varieties, particularly when facing issues like disease outbreaks, climate challenges, or poor shelf life. This is where molecular approaches come into play. By working directly with the genetic material of plants, these methods can accelerate the breeding process, enhance precision, and allow for the merging of desirable traits from various sources. With techniques ranging from marker-assisted selection to CRISPR-based genome editing, modern tools are paving the way for the creation of vegetable varieties that are not only high-yielding but also resilient to stress and nutritionally rich.

2. Molecular Marker Technologies in Vegetable Improvement

Molecular markers are unique DNA sequences that act like landmarks, guiding us to identify genes or quantitative trait loci (QTLs) associated with the traits we aim to improve. Common examples of these molecular markers include Restriction Fragment Length Polymorphisms (RFLPs), Simple Sequence Repeats (SSRs), Single Nucleotide Polymorphisms (SNPs), and Amplified Fragment Length Polymorphisms (AFLPs). Found naturally within a plant's genome, these markers are detected using various laboratory techniques.

These markers are vital in a process known as marker-assisted selection (MAS), where breeders select plants based on genetic data rather than just their visible traits. This method speeds up the breeding process and cuts down the number of generations needed to develop new varieties, ultimately saving time and resources. MAS has proven especially useful in vegetable crops, helping to enhance qualities such as disease resistance and overall fruit quality. For instance, in tomatoes, scientists have developed dense genetic maps with over 141,000 SNP markers, which have been key in identifying QTLs for resistance to Fusarium wilt and characteristics like fruit size.

Table 1. Examples of genomic resources in vegetable crops

Crop	Genome Resource Available	Important Trait Mapped Using Genomics	Relevance
Tomato	High-quality reference genome, SNP databases	Fusarium wilt resistance, lycopene content	Lycopene-rich, long-shelf-life varieties
Cucumber	Whole-genome sequence, SSR & SNP markers	Bitterness control, fruit length	Export-quality cucumber breeding
Brinjal	Draft genome sequence	Bacterial wilt resistance	Essential for Eastern & Southern India
Capsicum	SNP arrays	Heat tolerance, fruit color	Hot pepper and bell pepper improvement

3. Genomic Tools and Resources for Vegetable Crops

Recent breakthroughs in sequencing technology have opened the door to fully deciphering the DNA of various vegetable crops. Think of having a reference genome as having a comprehensive guide for a plant; it empowers researchers to pinpoint genes associated with crucial characteristics like disease resistance, flavor, and nutrient levels. Today, we can access high-quality genome assemblies for crops such as tomato, brinjal, cucumber, pepper, and carrot. In India, institutions like ICAR-Indian Institute of Vegetable Research (IIVR) and various state agricultural universities have played a significant role in generating and utilizing these genomic resources. Techniques like whole-genome resequencing and transcriptomics which involve examining gene activity under specific conditions help scientists grasp how plants respond to challenges like drought, heat, and pest invasions. This knowledge is paving the way for developing climate-smart vegetable varieties.

4. Marker-Assisted Breeding in Vegetables

Marker-assisted breeding (MAB) merges the age-old practices of plant breeding with cutting-edge molecular marker technology. The concept is straightforward: instead of waiting for plants to mature and reveal their traits in the field, breeders can utilize DNA markers to detect the existence of desired genes right at the seedling stage. This approach not only saves valuable time but also enhances accuracy.

Table 2. Examples of marker-assisted breeding in vegetable crops

Crop	Trait Targeted	Molecular Markers Used	Outcome
Tomato	Leaf curl virus resistance	SSR, SNP markers	Resistant varieties for Indian plains
Brinjal	Bacterial wilt resistance	SCAR markers	Improved wilt-tolerant hybrids
Cucumber	Powdery mildew resistance	SSR markers	High-yielding resistant lines
Okra	Yellow vein mosaic virus resistance	RAPD, SSR markers	Lines in advanced breeding stages

5. Genetic Engineering in Vegetable Crops

Genetic engineering is all about adding specific genes to a plant to give it a new characteristic. This could mean making the plant resistant to pests, boosting its nutritional value, or helping it withstand tough environmental conditions. Take vegetables, for example this technology has brought us innovations like Bt brinjal. This particular brinjal has a gene from the bacterium *Bacillus thuringiensis*, which helps protect it from pesky pests like the shoot and fruit borer. While Bt brinjal is already being sold in Bangladesh, in India, it's still going through regulatory checks because of concerns about biosafety. There are also other interesting examples, such as biofortified tomatoes that have more antioxidants and potatoes that produce less acrylamide when fried. Although genetically modified (GM) vegetables haven't taken off widely in India yet, research is actively happening in various government labs. The primary aim is to develop traits that solve specific agricultural problems in India like making chillies resistant to viruses and enhancing drought tolerance in tomatoes. At the same time, ensuring the safety for consumers and compatibility for exports remains a top priority.

6. Genome Editing: A New Frontier

Recently, genome editing has taken center stage as a ground-breaking method to tackle various challenges in agriculture.

Among the innovative tools available, CRISPR/Cas9, which stands for Clustered Regularly Interspaced Short Palindromic Repeats/CRISPR-associated protein 9, has gained significant attention. This cutting-edge technology empowers researchers to make precise modifications to plant DNA, enhancing desirable traits with remarkable accuracy and speed.

Table 3. Examples of CRISPR/Cas9 Applications in Vegetable Crops

Vegetable Crop	Target Gene(s)	Trait Improved	Important Outcome
Tomato	SlDML2	Fruit ripening	Delayed ripening
Tomato	Mlo1	Disease resistance	Resistance to powdery mildew
Tomato	GAD	Quality improvement	Increased GABA content
Tomato	IAA9	Parthenocarpy	Seedless fruits, altered leaf shape
Tomato	SlALMT9	Quality improvement	Increased malate content
Tomato	SlMYB12	Color	Reduced flavonoid content
Tomato	MAPK3	Disease resistance	Resistance to Botrytis cinerea
Potato	StALS1	Herbicide resistance	Tolerant to ALS-inhibiting herbicides
Potato	StPPO2	Enzymatic browning	Reduced browning
Cabbage	PDS	Phenotype	Albino phenotype for gene function study
Cucumber	eIF4E	Virus resistance	Resistance to multiple viruses
Eggplant	SmelPPO1-10	Enzymatic browning	Reduced browning
Kale	BoaCRTISO	Color	Reduced carotenoid/chlorophyll biosynthesis
Rapeseed	SFAR	Oil content	Increased seed oil content

(Source: Das et al., 2023**)**

Unlike conventional breeding practices that often require many generations to produce the desired outcomes, CRISPR/Cas9 can achieve specific genetic changes in just one generation. This dramatic reduction in time is a game changer for plant breeding. One of the standout features of CRISPR/Cas9 is its ability to directly modify genes that influence important agricultural traits, including disease resistance, nutritional value, and resilience to environmental stress. The precision of this technique has been bolstered by advancements in whole-genome sequencing and a better understanding of plant genes. By disabling, altering, or adding specific gene sequences, scientists can create new plant varieties that are both commercially appealing and able to withstand climate challenges. CRISPR/Cas9 could pave the way for the swift development of high-yielding, nutrient-rich, and resilient vegetable varieties that satisfy the demands of both farmers and consumers in our changing climate.

7. Future Prospects and Indian Context

The future of improving vegetable crops in India hinges on blending modern molecular techniques with traditional breeding methods and sustainable farming approaches. As climate change drives more frequent heat waves, droughts, and pest infestations, it's essential to adopt quicker and more accurate breeding techniques. Collaborations between public and private sectors, coupled with training programs for farmers, will facilitate the speedy rollout of enhanced crop varieties. For the majority of small and marginal farmers, who make up a large portion of India's agricultural community, these improved varieties must be made affordable. Main elements like seed systems, extension services, and awareness initiatives will be vital in connecting lab research to the benefits farmers experience in the field. Additionally, India's vast array of vegetable crops presents an opportunity to discover new genetic traits, which can help reduce reliance on imported genetic resources.

8. Conclusion

Molecular techniques have completely changed our perspective on vegetable breeding. With tools ranging from basic DNA markers to cutting-edge genome editing, we can now create high-yield, climate-friendly, and nutrient-dense varieties much faster than traditional breeding methods ever allowed. India, boasting robust research institutions and a variety of vegetable production areas, is in a prime position to leverage these advancements. By fusing scientific progress with policies that prioritize farmers, the nation can ensure that future vegetable crops not only satisfy nutritional needs but also meet market demands, all while standing up to environmental challenges.

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FROM PUNGENT TO PERFECT: WHY BLACK GARLIC IS THE NEW HEALTH TREND

INTRODUCTION

Garlic has been valued for centuries as both a culinary spice and a medicinal herb. But in recent years, a unique form of garlic, known as "*black garlic*", has gained global attention for its impressive health-promoting properties and distinctive taste. Unlike raw white garlic, black garlic undergoes a special aging process that transforms its flavour, texture and nutritional composition, making it not only a gourmet delicacy but also a functional food with wide-ranging benefits.

THE SECRET OF BLACK GARLIC: HOW WHITE TURNS TO BLACK

Black garlic is produced by subjecting fresh garlic bulbs to slow/controlled heat (60-90°C) and high relative humidity (80-90%) for several weeks. This process, often referred to as "*fermentation*", though technically it is a Maillard reaction, converts the sharp, pungent cloves into soft, jet-black segments with a sweet, tangy and umami-rich flavour. The process reduces the harshness of raw garlic while enhancing its antioxidant profile and bioactive compounds.

Originally popular in East Asia, especially in Korea, Japan and Thailand, black garlic has now become popular worldwide. Chefs appreciate its complex flavour that blends notes of molasses, tamarind and balsamic vinegar, while health enthusiasts value its elevated nutritional and medicinal qualities.

NUTRIENT MAKEOVER OF BLACK GARLIC

The transformation from white to black garlic isn't just cosmetic; it also changes its nutritional value. During the aging process, the pungent compound *allicin* is converted into *S-allyl-cysteine* (SAC), a more stable and highly beneficial compound. Black garlic is also richer in antioxidants, up to ten times higher than raw garlic, making it especially effective against harmful free radicals. In addition, it contains amino acids, polyphenols, vitamins and minerals such as calcium, magnesium and phosphorus.

HEALTH BENEFITS

- **Boosts heart health:** Regular consumption of black garlic can help lower cholesterol and triglycerides, while improving levels of "good" HDL cholesterol. Its compounds also support healthy blood circulation and may reduce the risk of heart disease.
- **Fights oxidative stress:** Rich in antioxidants, black garlic helps protect the body from oxidative damage, which contributes to aging and chronic diseases.

- **Supports immunity:** Like raw garlic, black garlic strengthens the immune system. Its bioactive compounds enhance the body's defense against infections and inflammation, keeping common illness at bay.
- **Helps control blood sugar:** Research suggests black garlic can improve insulin sensitivity and help manage blood sugar levels. This makes it a valuable dietary addition for people at risk of or managing type 2 diabetes.
- **Protects the liver and brain:** Studies indicate that black garlic may protect the liver from damage caused by toxins or fatty deposits. Its

antioxidants also safeguard brain cells, potentially reducing the risk of neurodegenerative diseases like Alzheimer's.

- **Shows anti-cancer potential:** Preliminary research highlights that black garlic compounds may slow cancer cell growth and promote the death of harmful cells. While human studies are still ongoing, the results so far are promising.

COOKING WITH BLACK GARLIC: DELICIOUS WAYS TO TRY IT

The beauty of black garlic lies not only in its health benefits but also in its versatility in cooking. Its sweet umami-rich flavour makes it easy to incorporate into daily meals. It can be spread on toast or crackers like a jam, or mixed into soups or sauces, or mashed into salad dressings, or topped on pizzas, pastas or roasted vegetables, or eaten plain as a chewy, flavourful snack. Unlike raw garlic, black garlic does not leave a strong odour or cause digestive discomfort, which makes it appealing to a wider audience.

CONCLUSION: A SUPERFOOD THAT SHINES IN THE DARK

Black garlic is a perfect example of how tradition and innovation can combine to create something extraordinary, by transforming humble garlic into a sweeter, softer and more nutrient-rich version, this "*black gold*" of the culinary world offers both taste and health in every bite.

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The Miracle Tree: *Moringa oleifera*

The 'Miracle Tree' - An Introduction to Drumstick

The drumstick tree, scientifically known as *Moringa oleifera*, is a fast-growing, drought-resistant tree native to the Himalayan foothills of India. It has been cultivated and revered for centuries in many parts of the world for its medicinal and nutritional properties, earning it the nickname 'The Miracle Tree.' Almost every part of the plant—from its leaves and pods to its flowers and seeds—is edible and packed with a unique combination of nutrients and bioactive compounds. For generations, *Moringa* has been a staple in traditional medicine systems like Ayurveda, where it is used to treat a wide array of ailments. Its remarkable ability to flourish in harsh conditions and its high nutritional density make it an invaluable resource for combating malnutrition, particularly in developing regions. In India, where it is most widely cultivated, the leaves and long, slender pods (drumsticks) are a common and affordable vegetable in many households.

The nutritional profile of *Moringa* is astounding. In fact, studies have shown that its leaves contain more vitamin C than oranges, more vitamin A than carrots, and more potassium than bananas. This makes it an excellent dietary supplement for people of all ages, including infants and nursing mothers who are particularly vulnerable to nutrient deficiencies. Its versatility allows for various preparations, such as drying the leaves into a powder that can be added to soups, sauces, and smoothies to enhance their nutritional value.

A Nutritional Powerhouse: Leaves, Pods, and Flowers

The most nutritious part of the *Moringa* tree is undoubtedly its leaves. Rich in provitamin A (as beta-carotene), B vitamins, vitamin C, manganese, and protein, the leaves are a complete nutritional package. This high concentration of nutrients makes them a potent source of antioxidants that help protect cells from oxidative stress and inflammation. The leaves also contain quercetin, polyphenols, and other bioactive compounds that contribute to their wide-ranging health benefits, including boosting the immune system and supporting cardiovascular health.

The pods, or drumsticks, are also a significant source of vitamins, particularly vitamin C, and dietary fiber. When cooked, they become a tender and flavorful addition to curries and soups. The immature seeds found inside the pods are also edible and contribute to the plant's nutritional value.

The flowers of the *Moringa* tree are a delicacy in some cultures and are a good source of calcium and potassium. They are often used in cooked dishes or fritters and are also a source of nectar, making them useful for beekeeping.

The nutritional benefits of *Moringa* leaves have been particularly recognized in India for their potential to combat vitamin A deficiency (VAD), a major public health problem. Dehydrated *Moringa* leaf powder has been successfully incorporated into supplementary foods for preschool children, demonstrating high compliance and effectiveness in improving nutrient intake. The leaves' high content of beta-carotene, which the body converts to vitamin A, offers a sustainable and natural strategy for preventing and treating VAD Medicinal Utilization and Health Benefits

The medicinal properties of the *Moringa* tree are extensive, with various parts of the plant being used for their therapeutic effects. The bioactive compounds in *Moringa* have been shown to possess antioxidant, anti-inflammatory, anti-diabetic, anti-hypertensive, antimicrobial, and anti-cancer properties

Regulating Blood Sugar: Compounds in *Moringa* have been shown to help reduce blood sugar spikes. This is due to the presence of isothiocyanates and other bioactive compounds that improve glucose tolerance and regulate blood sugar levels, making it beneficial for people with diabetes.

Lowering Blood Pressure: *Moringa* contains compounds like niaziminin and isothiocyanate that help prevent the thickening of arteries, which can lead to high blood pressure. The rich antioxidant profile also promotes better blood circulation.

Promoting Heart Health: The leaves and pods have been studied for their ability to lower cholesterol. Phenolic compounds and flavonoids in *Moringa* can help regulate lipid metabolism, thereby reducing the risk of cardiovascular diseases.

Liver Protection: *Moringa* has a hepatoprotective function, meaning it protects the liver from harmful toxins and can help speed up the healing process, even after damage from anti-tubercular drugs. It stimulates the production of glutathione, a key antioxidant for detoxification.

Anti-inflammatory and Antimicrobial Properties: The plant's natural analgesic and anti-inflammatory properties can help reduce swelling and alleviate pain. Furthermore, its potent antifungal and antibacterial compounds are effective against common infections.

Beyond Nutrition: Water Purification and Future Applications

Beyond its health and nutritional benefits, the *Moringa* tree offers a simple, low-cost method for water purification, which is a major concern in many developing nations. The seeds of the *Moringa* tree act as a natural flocculant.

The process involves crushing the dried seeds into a powder and mixing it with dirty, turbid water. The positively charged proteins in the seed powder bind to the negatively charged particles of dirt, clay, and bacteria, causing them to clump together and sink to the bottom of the container. This process, known as coagulation, can reduce the turbidity (cloudiness) of water by over 90% and achieve a bacterial reduction of 90-99%. This makes previously untreated water safer to drink and significantly reduces the risk of waterborne diseases.

This method is particularly valuable for household-level water treatment, as the tree is easy to grow and the process requires only simple, everyday tools. However, it is not a 'silver bullet' solution and works best for purifying surface water from rivers, streams, and lakes, rather than underground water contaminated with heavy metals like arsenic. The *Moringa* tree's ability to purify water, its incredible nutritional value, and its wide range of medicinal applications underscore its importance as a versatile and sustainable resource. Continued research into the bioactive compounds of *Moringa* promises to unlock even more of its potential for addressing global health and nutritional challenges.

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From Banking to Microgreens: Ajay Gopinath's Small-Space Success

Abstract

Ajay Gopinath, once a banker in Bangalore, turned into a successful microgreens farmer in Kerala. His journey started in 2017 after he noticed tiny greens served in a restaurant. Curious, he researched and began growing them at home. What started as a hobby soon grew into a business called Grow Greens. Today, in just 80 square feet, Ajay produces over 15 varieties of microgreens, harvesting around 5 kg daily and supplying them to hotels, gyms, and hospitals. Microgreens are rich in vitamins, minerals, and antioxidants, often more nutritious than mature vegetables. Ajay's work highlights their value as both healthy food and a profitable crop. The article also explains how microgreens are grown, stored, and kept safe, as well as the challenges and future opportunities in this field. Ajay's story shows how passion and persistence can turn a small idea into a big success.

Introduction

This article highlights the inspiring journey of Ajay Gopinath, who shifted from banking to microgreens farming and built a thriving business in a very small space. It explains how his curiosity led him to discover microgreens, their rich nutritional value, and their growing market demand. Along with Ajay's success story, the article also discusses the methods, challenges, and opportunities in microgreens production, showing how this emerging field combines health benefits with entrepreneurship.

Ajay's Journey into Micro-Greens Farming

In the heart of Kerala, Ajay Gopinath has transformed a small room in his home into a powerhouse of nutrition and entrepreneurship. Once a banker in Bangalore, Ajay now earns lakhs by growing micro-greens – tiny seedlings of vegetables and herbs – and supplying them to a wide network of customers.Ajay's journey into micro-greens farming began in 2017, when a simple dining experience changed the course of his life. While eating at a restaurant, he noticed small green shoots on his plate and grew curious about their purpose. Research revealed that these were micro-greens, packed with nutrients and not just a garnish. Fascinated, Ajay began experimenting with growing them – initially for his personal consumption.The enthusiastic response from friends and well-wishers who tasted his harvest inspired him to take things further. What began as a hobby soon turned into a thriving business. Today, in 2025, Ajay cultivates over 15 varieties of micro-greens in just 80 square feet of space. Every day, he harvests nearly 5 kilograms of these greens and supplies them to more than 20 channels, including hotels, gyms, and hospitals.

Nutritional Value of Micro-Greens

Micro-greens are known for their dense nutritional value. For instance, just 25 grams of red cabbage micro-greens provide the same nutritional value as one kilogram of mature red cabbage. They are rich in antioxidants, vitamins C, K, and B12, and minerals such as potassium, iron, zinc, magnesium, and copper, making them a true superfood.

Grow Greens

Ajay runs his venture under the name Grow Greens, but his mission goes beyond financial success. He is passionate about making micro-greens accessible to everyone and is always ready to guide those interested in setting up their own micro-greens farms.Ajay Gopinath's story is an inspiring example of how passion, curiosity, and persistence can transform a simple idea into a sustainable business that benefits both the entrepreneur and the community.

The State of Micro-Scale Vegetable Production

Over the last two decades, consumer interest has shifted toward healthy, functional foods, creating a niche market for specialty crops like microgreens. Often called 'vegetable confetti' due to their use as a culinary garnish, these tender, immature greens are harvested soon after germination, typically within 7 to 21 days, when their cotyledons are fully expanded and the first true leaves have appeared.

Defining and Distinguishing Microgreens

Microgreens are a class of specialty crops grown from the seeds of vegetables, herbs, and grains. They are harvested by cutting the stem just above the soil surface. This distinguishes them from sprouts, which are typically grown in a dark, moist environment and consumed whole, including the seed and root. In contrast, microgreens have a stronger flavor, a wider range of colors and shapes, and a higher concentration of phytonutrients and minerals like ascorbic acid, carotenes, and calcium than their mature counterparts.

Growing Microgreens: From Seed to Harvest

Seed and Sowing

The high volume of seeds needed represents a major cost for microgreen production. Although microgreens haven't been linked to foodborne outbreaks, using contaminated seeds poses a risk. Therefore, seeds must undergo sanitary treatments. Some species require pre-sowing treatments like soaking or priming to improve and standardize germination. The optimal sowing rate varies by species and is based on seed weight and desired density. An excessive sowing rate can lead to elongated shoots and fungal diseases due to poor air circulation.

Growing Media

Microgreens can be grown in various systems, including soil and soilless media, and in different environments, from open air to controlled indoor settings. The ideal growing media should have a pH of 5.5-6.5 and good water and air retention. Sustainable alternatives like coconut coir and natural fibers are gaining traction, as they can also be fortified with nutrients or inoculated with beneficial microorganisms.

Pre-harvest Factors Influencing Quality

Species Selection

A wide range of species from various families, including Brassicaceae and Chenopodiaceae, are used for microgreens. Genetic variability between and within species significantly affects the concentration of phytonutrients, vitamins, and minerals. However, species with strong, often acrid flavors—like those from the Brassicaceae family—tend to be less preferred by consumers than sweeter varieties.

Plant Nutrition and Biofortification

Biofortification, which involves enriching microgreens with essential minerals like magnesium and iron by modulating the nutrient solution, is a feasible way to improve their nutritional content. Appropriate nutrient management can also reduce anti-nutritional factors, such as nitrates, which some species like arugula tend to accumulate.

Lighting Conditions

Light quality, intensity, and photoperiod all affect microgreen growth and phytochemical biosynthesis. • Light Quality: LED spectral qualities (blue, red, green) can enhance specific phytochemicals. • Light Intensity: Moderate intensity improves carotenoids and phenols while reducing nitrates. • Photoperiod: Continuous red light can increase carotenoid concentration and antioxidant capacity.

Post-harvest Quality and Storability

Handling and Pre-storage Applications

Microgreens are highly perishable due to their young, high-respiration tissues. They require gentle harvesting with sharp blades to avoid bruising and immediate cooling to slow down senescence. Pre-harvest calcium spray applications have shown significant promise, improving quality and extending shelf-life.

Storage and Packaging

Temperature is the most crucial factor for extending microgreens' shelf-life. They are best stored at around 10-12°C. Modified Atmosphere Packaging (MAP) is also essential, with high oxygen transmission rates to avoid anaerobic conditions.

Microbial Safety

Microgreens, harvested close to the soil, have a high initial microbial count. While chilling and proper MAP can help, sanitation is critical. Improved drying methods and non-hypochlorite sanitizers are being researched to reduce microbial populations without compromising quality.

The Path Forward: Challenges and Opportunities

The microgreen industry is still in its infancy, with immense potential. Future research should focus on: • Sustainable Practices: Eco-friendly seed sterilization and growing media. • Genotype Exploration: Indigenous and wild genetic material. • Optimizing Production: Manipulating lighting, fertilization, and harvest timing. • Improving Shelf-life: New packaging technologies and handling protocols.

By addressing these research areas, growers can tap into the immense potential of microgreens as a nutritious and gastronomically appealing superfood.

Conclusion

In conclusion, the article not only shares Ajay Gopinath's inspiring shift from banking to microgreens farming but also emphasizes the immense potential of microgreens as a nutritious and profitable crop. It shows how curiosity, persistence, and innovation can turn a small idea into a sustainable business that benefits both individuals and the community. By combining Ajay's success story with insights into production methods and challenges, the article underlines the purpose of promoting microgreens as a healthy food choice and an emerging opportunity in modern agriculture.

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Vertical farming and hydroponics the Opportunity in Urban India

Abstract:
Vertical farming and hydroponics are rapidly growing segments of urban agriculture in India, offering a strategic solution to the country's challenges of dwindling arable land, water scarcity, and rising demand for fresh, quality produce. The market for these technologies is projected to experience a robust Compound Annual Growth Rate (CAGR) of over 21% from 2024 to 2033, with the vertical farming market alone expected to reach an estimated USD 579.7 million.

The Opportunity in Urban India

The market for vertical farming and hydroponics in India is experiencing rapid growth. Reports suggest the vertical farming market, which was valued at around USD 82.7 million in 2024, is expected to reach USD 579.7 million by 2033, with a robust CAGR of 21.50%. Similarly, the hydroponics market, valued at USD 506.7 million in 2024, is projected to reach USD 2,292.7 million by 2033. This growth is driven by several key factors:

Shrinking Arable Land: As urban areas expand, agricultural land is diminishing. Vertical farming utilizes limited urban spaces like rooftops, terraces, basements, and abandoned warehouses, making it a perfect solution for land-constrained cities.

Year-Round Production: Unlike traditional farming which is seasonal, vertical farming allows for year-round crop production, ensuring a steady supply of fresh produce irrespective of external weather conditions like droughts, floods, or extreme temperatures

.Business Opportunities in Urban Vertical Farming & Hydroponics

There are several lucrative avenues for agri-entrepreneurs in this space:
Commercial Production of High-Value Crops: Focus on crops that are well-suited for controlled environments and have high market demand. These include leafy greens (lettuce, spinach, kale), herbs (basil, mint, coriander), microgreens, and some fruits like strawberries. These crops have a shorter cultivation cycle and can command premium prices.

OPPORTUNITIES

Space Efficiency: Vertical farming utilizes vertical space in urban areas, enabling crop cultivation in locations like rooftops, warehouses, or even shipping containers, thereby minimizing the need for extensive Rural land.

Enhanced Food Security: By growing food within cities, urban residents gain access to fresher produce with reduced transportation costs, leading to improved food security and reduced reliance on long supply chain.

MARKET GROWTH

The Indian vertical farming market is experiencing robust growth, presenting opportunities for investors and businesses in areas like Bengaluru, Hyderabad, and Chennai.

CHALLANGES:

High Initial costs: The initial investment in technology, infrastructure, and energy required for vertical farms can be substantial, presenting a barrier to entry for many.

Lack of expertise: A shortage of skilled labor and expertise in operating and maintaining advanced vertical farming systems poses a challenge to scaling up operations.

Government Support: Increased government support, including policies, incentives, and funding, is essential to make vertical farming more accessible and viable in India.

Key Technologies & Methods:

Hydroponics: A soil-less method where plant roots are nourished with nutrient-rich water solutions:

Aeroponics: A technique where plant roots are suspended in the air and misted with nutrient solutions.

CONCLUSION:

Vertical Farming: Revolutionizing Urban Agriculture for a ...Vertical farming and hydroponics offer significant opportunities in urban India, addressing food security, land scarcity, and water challenges by providing fresh, pesticide-free produce year-round in controlled, space-efficient environments.

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How To Protect Crops From Heavy Rains

Abstract

Heavy rains in many parts of the Telugu states have led to severe crop losses due to prolonged waterlogging. Standing crops such as paddy, cotton, maize, and vegetables are highly vulnerable when excess rainwater accumulates in fields. If water stagnates for more than three to four days, root systems weaken, nutrient absorption decreases, and crops begin to wilt, yellow, and dry up. This article discusses effective crop management practices during heavy rainfall conditions, including immediate drainage, crop-specific nutrient sprays, and the use of short-duration or flood-tolerant varieties. These measures aim to minimize yield losses and ensure sustainability in rain-affected areas.

Introduction

The Indian farming system is highly dependent on monsoon rains. While timely rainfall supports crop growth, excessive and untimely heavy rains often result in waterlogging and crop damage. The frequency of such events has increased due to climate variability, causing heavy losses to farmers. Crops such as paddy, cotton, maize, and vegetables are particularly vulnerable because their root systems are sensitive to excess water conditions. To safeguard crops and maintain productivity, farmers need timely management strategies. This article highlights the impact of heavy rains on major crops and suggests practical measures recommended by agricultural experts.

Impact on Paddy

Paddy is one of the most widely cultivated crops in rain-fed regions. Although it requires standing water, prolonged waterlogging (beyond 5 days) reduces oxygen availability and damages the root system. Farmers should immediately drain excess water through village-level drainage channels. In case of crop failure, short-duration and submergence-tolerant varieties such as MTU-1010 and KNM-118 can be used. Replanting within 15–20 days can help recover yield losses.

Management of Cotton

Cotton plants are highly sensitive to waterlogging. Continuous water stagnation results in nutrient deficiency, poor root growth, and plant wilting. To restore crop vigor, foliar sprays of potassium nitrate (13:0:45 at 1%) or multi-nutrient mixtures (19:19:19 at 2%) are recommended. Farmers should repeat foliar sprays at weekly intervals if crop stress persists. In cases of severe damage, partial re-sowing is advisable.

Maize Response to Heavy Rains

Maize is another sensitive crop that cannot tolerate stagnant water. Prolonged flooding severely affects the root zone and hampers nutrient absorption. Farmers should ensure proper drainage immediately after heavy rains. Foliar application of 13:0:45 (1%), 19:19:19 (2%), or 28:28:0 (2%) enhances recovery. Urea at 10 g per liter of water may be sprayed twice at weekly intervals to restore crop health.

Vegetable Crops Under Flood Conditions

Vegetables such as tomato, brinjal, chili, and okra are prone to root rot under waterlogging. Timely drainage is crucial to prevent crop mortality. Once the water recedes, foliar sprays of 2.5 g urea + 2.5 g potassium nitrate per liter of water should be applied at 10-day intervals. This practice helps strengthen plant recovery and reduce flower and fruit drop.

General Recommendations

- Immediate drainage of water is essential in all crops.
- Adoption of raised beds or ridge-furrow systems minimizes future waterlogging risk.
- Use of flood-tolerant and short-duration crop varieties reduces vulnerability.
- Farmers should coordinate at village level to strengthen drainage networks.

Conclusions

Heavy rains pose a major threat to crop productivity by causing prolonged waterlogging and nutrient deficiencies. Crop losses can be minimized through timely drainage measures, crop-specific nutrient sprays, and the adoption of flood-tolerant varieties. Farmers should remain vigilant during monsoon months and implement precautionary practices. Strengthening drainage systems and adopting climate-resilient varieties are vital to sustaining agricultural production in rain-affected regions.

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PADDY STRAW MANAGEMENT PRACTICES

Introduction:

Rice (*Oryza sativa* L.) a staple food of more than half of the population of the world, provides food security and livelihood for millions of people. China ranks first in the world, and India ranks second in paddy consumption worldwide. Paddy, wheat, maize are the world's three leading food crops and together constitute 50% of the total calories consumed by humans, wheat provides around 20%, rice 16%, and maize 13%. Paddy is the main crop of India with 45.07 mha area.

Producing 122.27 million tons of rice per year, when cereal crops are harvested, half of the process ends with agricultural waste as crop residue or straw. Thus, the increase in productivity and area under cultivation of paddy straw in the field is the cost-efficient method for rapid and complete residue removal for next crop cultivation, especially for those practicing double or triple cropping per year for commercially purposes but it results in the loss of major & minor soil nutrients from the crop field and loss of crop productivity. It is also responsible for infertility and imbalance of nutrients. Therefore, it has become important to explore sustainable and effective solutions for them.

Why Need to Management

- **Effect on Environment:** Paddy straw (rice straw) burning has a significant negative impact on the environment. Burning of paddy crop residues causes air, water and land pollution, thus, affecting the environment.
- **Air Pollution:** Releases harmful gases: Burning emits large amounts of carbon dioxide (CO_2), carbon monoxide (CO), methane (CH_4) and nitrous oxide (N_2O). Contributing to greenhouse gas buildup.
- **Smog formation:** Combines with other pollutants to form thick smog, especially in places like Northern India during winter.

Soil Health Degradation:

- Destroys beneficial microbes: High heat from burning kills microorganisms essential for soil fertility. Burning leads to loss of nitrogen, phosphorus, potassium, and sulphur - vital for crop growth.
- **Climate change:** Paddy straw burning contributes to global warming by increasing the concentration of greenhouse gases in the atmosphere.
- **Air-quality Impacts:** Burning releases pollutants like particulate matter (PM 2.5 and PM10) carbon monoxide (CO) nitrogen oxides N_2O, and volatile organic compounds (VOCs) into the atmosphere.

- **High AQI levels:** Cities like Delhi and Kanpur experience significantly elevated Air Quality Index (AQI) levels during the winter months due to stubble burning, often reaching "severe" and "very poor" categories.

Specific City Examples:

- **Delhi:** Stubble burning from neighboring states like Punjab and Haryana is a major contributor to Delhi's air pollution, especially during the winter months. The AQI value of Delhi reaches 20 µg/m3.
- **Kanpur:** Similar to Delhi, Kanpur also experiences poor air quality during the winter due to stubble burning, leading to health concerns. The AQI value of Kanpur reaches 55µg/m3.
- **Punjab:** Similar to Delhi, Punjab also experiences poor air quality during the winter season due to crop stubble burning, leading to health infections (such as individuals with respiratory conditions, children, and the elderly). To take necessary precautions, this includes minimizing outdoor activities, using air purifiers indoors, and wearing masks. The AQI value of Punjab reaches 172µg/m3.

How to manage Paddy Straw:

The useful practices to be adopted for the management of paddy straw are discussed as under:

- **Mulch:** Crop residue can be collected and used as mulch in succeeding crop. A lot of machinery can be used for this purpose. Such as no-till drill has positive impacts on wheat yield. Mulch increased production of wheat grain & reduced crop water use by 3-11% and improved water use efficiency by 25% as compared to no mulch treatment.It also regulates canopy temperature at grain-filling stage in wheat to mitigate the terminal heat effects (Gupta *et al.*, 2010 and Jat *et al.*, 2009).
- **Bedding material for cattle:** In agriculture, paddy straw can be used as bedding material in cattle yards. The scientists of Punjab Agricultural University, Ludhiana also advise the farmers to use paddy straw as a bedding material in winter season and paddy straw as litter provides comfortable and hygienic environment to the cattle which will ensure better milk production and reproductive efficiency of animals. (Kumar *et al.*, 2015, Kangbo *et al.*, 2010 and Singh *et al.*, 1995).
- **Compost for mushroom cultivation:** As per the statistics of Food and Agriculture Organization, India produced 0.24 million tons in 2000 but had 1.56 million tones production in 2020. India sixth ranked in the world in mushroom production. Cultivation of mushrooms requires paddy straw with some special moisture, length and temperature (Yashiro and Duang, 2015 and Kaushik *et al.*, 2018). Relative humidity for mushroom about 75-85% and temperature 35°C (Thiribhuvanamala *et al.*, 2012).
- **Dry fodder:** Paddy straw can be used as dry fodder for ruminants in the developing countries. Kumar (2015) reported that only 7% of the total paddy straw is used as animal fodder whereas, 45% of wheat straw is used as animal fodder. Nutritive value of paddy straw can be improved with physical, chemical and biological treatments. Physical treatment such as crushing, are mainly done to break the

silicified encrusting layers of straw (Liu *et al.*, 1999).

- While chemical treatment of straw with alkali is done to improve both apparent digestibility, bacterial colonization on cellulose and voluntary intake of straw (Vadiveloo, 2000).
- **Raw material for Fiber and Pulp:** Rice straw can be processed into fiber and pulp, used in various industries like paper and textiles.
- **Paddy straw for nutrients the soil:** Paddy straw can play a significant role in improving soil nutrients when managed properly. Paddy straw adding organic matter. Decomposition of paddy straw enriches the soil with organic carbon, improving soil structure and water-holding capacity. (Yadvinder-Singh; Bijay-Singh; Timsina, J., 2005).

  Paddy straw has both nutrient and calorific values (Yashiro and Buong, 2015). In composting process, microorganisms and earthworms utilize organic matter of crop stubbles and convert the dry matter into soil nutrients (Bernal, 1996; Aon, 2013). In composting process, the carbon to nitrogen ratio, moisture content, temperature, pH value, degree of aeration and structure of the waste material are the factors that affect quality of the compost (Rashad *et al.*, 2010; Liet *et al.*, 2007).
- **Present Status:** Paddy straw burning is a significant environmental concern in India, particularly in northern states like Punjab and Haryana. The practice releases harmful pollutants into the air, contributing to severe air pollution, smog, and health issues. Health Risks: Exposure to air pollution from paddy straw burning can cause respiratory problems, cardiovascular diseases, and even cancer.
- Ministry of Agriculture and Farmers Welfare, Government of India - "Agricultural waste management" report (2020) highlights the issue of paddy straw burning and its environmental impacts.
- India Institute of Science (IISc): A study published in the Journal of Environmental Management (2018) estimates the emissions from paddy straw burning in India and its impact on air quality.
- India produces over 500 million tons of crop waste annually, with 140 million tons remaining unused and 92 million tons being burned.
- Punjab and Haryana are among the top contributors to paddy straw burning, with around 35 million tons of paddy crop waste burned annually.

Conclusion: This article focuses on harmful effects of the crop residue burning and various methods to overcome the harmful consequences. Paddy straw burning, though a quick and cost-effective method for farmers to clear fields, poses serious environmental and health hazards. It contributes significantly to air pollution, greenhouse gas emissions, and deteriorating soil health. Sustainable alternatives such as in-situ crop residue management, use of Happy Seeder machines, and converting stubble into biofuel or compost must be promoted, with coordinated efforts from the government, farmers, and society, we can move towards eco-friendly farming practices and reduce the harmful impacts of stubble burning.

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Beyond the Genetic Code: Translational Tricks of RNA Viruses

Introduction

With the world's population rising steadily, the demand for food is growing at an unprecedented rate. To meet this challenge, enhancing both the production and productivity of food crops is crucial. However, plants, being immobile organisms, are constantly exposed to various environmental stresses—both biotic (such as pests and diseases) and abiotic (such as drought and extreme temperatures). These stresses significantly hinder their growth, development and ultimately, reduce crop yields. Therefore, addressing these challenges is vital to ensuring sustainable food security for the future. Among the various biotic stressors affecting crops, viral infections are particularly detrimental, causing significant reductions in both yield and quality. While fungal and bacterial diseases can often be managed through chemical treatments, viral pathogens pose a greater challenge due to their intricate relationship with plant hosts, making them difficult to control. Over 2,000 plant viruses have been identified, though only a fraction successfully cause disease. Despite this, viral infections are responsible for 10–15% of global food production losses, posing a serious threat to food security as the population continues to grow. Viruses consist of a small genome, either DNA or RNA, enclosed within a protein coat. This minimal genome typically encodes just a few key proteins, such as coat proteins, movement proteins, and replication enzymes. However, these are not sufficient for independent viral replication, which is why viruses are obligate intracellular parasites, relying on the host cell's machinery for survival. Viruses hijack host eukaryotic initiation factors (eIFs) through mechanisms like internal ribosome entry sites (IRES) and cap-independent translation enhancers (CITE). Potyviruses, for instance, use VPg proteins to interact with host eIF4E or eIFiso4E, enabling translation. Targeting eIFs could enhance crop resilience, contributing to improved food security and innovative virus management.

Strategies of Viral mRNA Translation: Mimicking and Bypassing Cellular Mechanisms

Viruses rely entirely on the host's translational machinery to express their proteins, yet they face a critical challenge: their RNAs often lack the canonical signals that eukaryotic ribosomes require for initiation. To overcome this barrier, viruses have evolved diverse molecular strategies that either imitate host mRNA features or exploit unique RNA elements to initiate translation. These mechanisms illustrate the remarkable adaptability of viruses in ensuring their replication and survival.

1. Mimicking the 5′ Cap of Cellular mRNA

In eukaryotic cells, translation initiation typically depends on a 7-methylguanosine cap at the 5′ end of mRNA, which is recognized by the eIF4F complex. Many viruses replicate outside the nucleus and therefore cannot rely directly on host capping enzymes. To solve this, they employ a variety of tactics:

- Utilizing host machinery: Several double-stranded DNA viruses replicate in the nucleus and exploit the host's capping system.
- Encoding their own capping enzymes: Cytoplasmic viruses such as poxviruses and coronaviruses encode specialized enzymes that synthesize the cap structure de novo.
- Cap-snatching: Some negative-sense RNA viruses, most famously influenza viruses, cleave the 5′ capped fragments of host mRNAs and use them as primers for viral RNA synthesis. Similar processes have been reported in other viral families, including totiviruses.
- Cap modification for immune evasion: In addition to acquiring a cap, certain viruses modify the cap chemically to escape recognition by host innate immune sensors and to avoid RNA degradation.

Despite the prevalence of cap-dependent strategies, many viruses have evolved ways to bypass the requirement for a cap, relying instead on cap-independent mechanisms such as IRESs and 3′ CITEs.

2. The Viral Protein Genome-Linked (VPg)

In several positive-sense single-stranded RNA (+ssRNA) viruses, a small viral protein termed VPg is covalently attached to the 5′ end of the genome. VPg plays a dual role:

- Primer for replication: It is uridylated and provides a hydroxyl group that acts as a primer for RNA-dependent RNA polymerase during RNA synthesis.
- Cap mimic for translation: In potyviruses, VPg functionally substitutes for the 5′ cap by interacting with host translation initiation factors, especially eIF4E or its isoform eIFiso4E. This interaction enables viral RNAs to compete effectively with cellular mRNAs.

Studies using mutagenesis and binding assays have shown that disrupting VPg–eIF4E/eIFiso4E interactions abolishes viral infectivity, emphasizing the critical role of VPg in translation and replication (Anuradha *et al* 2022). In rice-infecting viruses such as Rice Yellow Mottle Virus (RYMV), VPg preferentially interacts with eIFiso4G, reflecting host-specific adaptations. Thus, VPg is a multifunctional element that ensures both RNA synthesis and efficient recruitment of host translation machinery (Hebrard *et al* 2010).

3. Internal Ribosome Entry Sites (IRES)

Many RNA viruses circumvent the need for a 5′ cap by harboring Internal Ribosome Entry Sites (IRESs)—structured RNA elements that recruit ribosomes directly to an internal position on the viral RNA.

- Discovery and function: First identified in picornaviruses such as poliovirus and encephalomyocarditis virus, IRESs were shown to enable translation initiation in bicistronic constructs, demonstrating that ribosome entry could occur independently of the 5′ end.
- Factor requirements: Different classes of IRESs rely on distinct sets of initiation factors. Some, like the EMCV IRES, can directly position the ribosome at the start codon, while others, such as poliovirus IRES, require limited scanning.

- Role of ITAFs: IRES trans-acting factors (ITAFs) assist in stabilizing IRES structures and promoting efficient translation, particularly under conditions where host cap-dependent translation is suppressed. For example, poliovirus proteases cleave host factors like eIF4G and PABP, selectively favoring IRES-driven viral translation (Kolupaeva *et al* 2003).

4. Cap-Independent Translation Enhancers (CITEs) at the 3′ End

Plant RNA viruses often lack a 5′ cap but compensate by using structured elements in the 3′ untranslated region (UTR), known as Cap-Independent Translation Enhancers (CITEs). These motifs recruit initiation factors or ribosomal subunits and communicate with the 5′ end via long-distance RNA-RNA interactions, effectively circularizing the genome.

Major classes of CITEs include:

- Translation Enhancer Domain (TED): First described in Satellite Tobacco Necrosis Virus, directly binds eIF4F.
- Barley Yellow Dwarf Virus-Like Elements (BTEs): Y-shaped structures that recruit eIF4G.
- Pseudoknot Translation Enhancers (PTEs): Mimic the cap by binding eIF4E.
- Tobacco Necrosis Virus Stem-Loop (TSS): Engages in kissing-loop interactions with the 5′ UTR.
- Umbravirus CITEs: Bind both eIF4F and ribosomal subunits.

Through these diverse configurations, CITEs substitute for the absent 5′ cap and ensure efficient viral protein synthesis.

5. tRNA-Like Structures (TLSs)

Another widespread adaptation is the presence of tRNA-like structures (TLSs) in the 3′ UTRs of plant RNA viruses such as Tymoviridae and Bromoviridae. These elements mimic canonical tRNAs both structurally and functionally.

- Roles in replication and translation: TLSs act as signals for the addition of a CCA tail, regulate negative-strand synthesis, and interact with elongation factor eEF1A to enhance translation.
- Aminoacylation requirement: In Turnip Yellow Mosaic Virus (TYMV), the TLS must be aminoacylated to achieve maximal translational efficiency, functioning synergistically with the 5′ cap (Matsuda and Dreher 2006).
- Diverse functions in different viruses: While TLSs promote translation in TYMV and Brome Mosaic Virus, in Tobacco Mosaic Virus (TMV) they instead function primarily as promoters of minus-strand synthesis. In TMV, efficient translation is driven instead by a 3′ pseudoknot and the 5′-UTR “omega” element, which interacts with heat shock protein 101 and the eIF4F complex.

The omega sequence of TMV has been harnessed in biotechnology as a powerful enhancer of transgene expression, highlighting the applied potential of viral RNA elements.

Optimization of Coding Capacity in RNA Viruses

RNA viruses have small genomes but remarkable efficiency in how they encode information. To overcome their size limitation, many of them employ overlapping genes that allow multiple proteins to be produced from the same RNA template. This compact design is made possible through specialized translation mechanisms that alter ribosomal behavior. The three most prominent strategies are: (i) leaky scanning, where ribosomes skip initial start codons and initiate translation further downstream, (ii) programmed ribosomal frameshifting (PRS), which shifts the reading frame during elongation, and (iii) stop-codon readthrough, where termination is suppressed to extend translation beyond canonical stop signals. Together, these recoding mechanisms enable viruses to generate several proteins from a single transcript, maximizing genetic output without expanding genome size.

1. Leaky Scanning

In leaky scanning, ribosomes do not always recognize the first AUG start codon. Instead, some ribosomes continue scanning until they encounter a downstream initiation codon. This process can generate either shorter versions of a protein (when the downstream codon is in the same reading frame) or entirely different proteins (if it is in an alternate frame).

The initiation efficiency depends strongly on the nucleotide context surrounding the AUG. The so-called Kozak consensus sequence (caA(A/C)aAUGGCg) represents the most favorable context for initiation. Plant viruses often exploit variations of this rule. For example, Potato virus X (PVX) and Barley stripe mosaic virus (BSMV) rely on leaky scanning to express their *triple gene block* (TGB) proteins, which are essential for cell-to-cell movement. In some cases, non-AUG codons such as CUG or GUG serve as alternative initiation sites. Shallot virus X (ShVX) uses CUG to produce TGB3, while Maize chlorotic mottle virus (MCMV) and Pelargonium line pattern virus (PLPV) also utilize non-canonical initiation codons (Lezzhov et al., 2015).

In Poleroviruses and Luteoviruses, small overlapping ORFs are initiated in this way, often influenced by nearby RNA secondary structures (Smirnova et al., 2015). Similarly, in Tymoviruses, the relative spacing of AUG codons is a crucial determinant of translation efficiency (Matsuda & Dreher, 2006).

2. Programmed Ribosomal Frameshifting (PRS)

Programmed ribosomal frameshifting is a translation recoding event where ribosomes slip by one nucleotide, usually in the −1 direction, and switch into a different reading frame during elongation. This allows two overlapping ORFs to be translated into distinct proteins.

Frameshifting typically requires two elements:

1. A "slippery" heptanucleotide motif (commonly X_XXY_YYZ, where X and Y are any nucleotide and Z is usually not G).
2. A downstream RNA secondary structure such as a stem-loop or pseudoknot that physically stalls the ribosome.

This mechanism is well documented in plant viruses such as Sobemoviruses, Umbraviruses, Dianthoviruses, and members of the Luteoviridae family. A classic example is Barley yellow dwarf virus (BYDV), where a −1 frameshift is essential for producing the RNA-dependent RNA polymerase (RdRp). In BYDV, long-range interactions between the 3′ untranslated region (UTR) and the frameshift site fine-tune the efficiency of this process (Barry and Miller 2002).

3. Stop-Codon Readthrough

Another mechanism to expand coding capacity is stop-codon readthrough, in which ribosomes ignore a stop signal and continue translating, producing proteins with extended C-terminal domains.

The efficiency of readthrough depends on both the nucleotide context of the stop codon and RNA structures nearby (Firth and Brierley 2012). Viruses often carry long-distance RNA motifs that interact with local structures to regulate this process.

Three main classes of readthrough signals are known:

1. Type I: UAG stop codon followed by the consensus sequence CARYYA. Used by Tobamoviruses, Benyviruses, and Pomoviruses to synthesize replicases (Skuzeski et al., 1991).

2. Type II: UGA stop codon followed by CGG or CUA triplets and a downstream stem-loop located ~8 nt away. Found in Tobraviruses and Furoviruses.

3. Type III: UAG stop codon followed by a purine-rich region and a compact pseudoknot, seen in Tombusviruses such as *Carnation Italian ringspot virus* (CIRV) (Cimino et al., 2011).

Additionally, many plant viruses contain tRNA-like structures (TLSs) at their 3′ ends. These motifs can be aminoacylated with specific tRNAs (e.g., valine, histidine, or tyrosine) and bind translation elongation factor eEF1A, stabilizing the viral RNA and enhancing translation initiation. For example, the TLS of Turnip yellow mosaic virus (TYMV) has strong ribosome affinity and contributes to replication efficiency.

Conclusion

Viruses exhibit extraordinary ingenuity in controlling translation of their RNAs. By mimicking the 5′ cap through VPg or cap-snatching, employing structured RNA elements like IRESs and CITEs, or exploiting tRNA-like motifs, they successfully bypass host defenses and secure efficient protein synthesis. These strategies not only illustrate the molecular arms race between viruses and their hosts but also provide valuable tools for biotechnology and synthetic biology, where viral elements are increasingly applied to enhance gene expression systems. RNA viruses achieve extraordinary genetic efficiency through translational recoding strategies such as leaky scanning, ribosomal frameshifting, and stop-codon readthrough. These mechanisms allow a single RNA transcript to encode multiple proteins, conserving genome size while enabling complex regulation of viral protein synthesis. The reliance on precise RNA motifs, secondary structures, and long-distance interactions highlights the sophisticated level of control viruses exert over host ribosomes, ensuring successful infection and replication.

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Makhana in Bihar: Production, Importance, and the Way Forward

Abstract

Makhana which is also known as fox nut, is a high-value aquatic crop with deep cultural and economic roots in Bihar. The state contributes the huge share of India's makhana output, with hundreds of thousands of rural households engaged across cultivation, harvesting, and processing. This article synthesizes the latest open data and official reports to present Bihar's production landscape, the value chain from pond/field to pop, recent policy and market shifts (GI tag, mechanization, export push), and a clear, step-by-step guide to cultivation and processing.

Introduction

Makhana has moved from a regional delicacy to a nationally recognized "superfood", buoyed by rising urban demand, exports, and product innovation. Bihar is the heartland of this transformation: wetlands across the Mithila belt and field systems in north and east Bihar anchor most of India's production and livelihoods in the crop. At the same time, the sector is shifting from labour-intensive, traditional processing to mechanized techniques; from unorganized marketing to FPO-led aggregation; and from pond-only cultivation to hybrid pond-and-field systems for maintaining higher productivity.

Bihar's Production Footprint—What the Latest Numbers Say

Dominance in India: Bihar accounts for 85–90% of India's makhana production; cultivation and processing employ roughly 5 lakh people statewide.

Area & output trend: Official state data show area rising from 13,000 ha (2012–13) to 35,000 ha (2021–22), seed output from 20.8 thousand MT to 56.4 thousand MT; and popped output from 9.4 to 23.7 thousand MT. Productivity gains are linked to improved varieties 'Swarna Vaidehi' and 'Sabour Makhana-1' (with seed subsidies up to 75%).

District leaders: Among 21 producing districts, production has recently surged in 'Purnia' and 'Katihar' (pop output 5.2 and 4.9 thousand MT in 2021–22), while traditional strongholds 'Darbhanga' and 'Madhubani' remain vital.

Yield: Pond systems average about 1.7–1.9 t/ha of seed, carefully managed field systems under integrated nutrient management have reported up to 3.2 t/ha in research settings.

Why Makhana Matters to Bihar?

Livelihoods & inclusion: The crop's tasks like nursery raising, weeding under water, seed retrieval, roasting, and popping helps in providing seasonal work to smallholders, landless labourers, women's groups, and fishers. Mechanization is beginning to reduce drudgery without eliminating jobs by shifting labour to grading, packing, and value addition.

Cultural economy: Popped makhana is central to fasting/ritual cuisines across India and carries a quality reputation through "Mithila Makhana," which received a 'GI tag on 16 August 2022'—a branding boost for Bihar's exporters and FPOs.

Nutrition: Popped makhana is low-fat, carbohydrate-rich and provides '8–9% protein', minerals (iron, calcium, magnesium), and all essential amino acids, an appealing non-cereal snack for health-conscious consumers.

Markets & exports: Prices and demand climbed after 2020 as domestic snacking and global interest rose, exports (mostly to USA, UK, Australia) are small but growing. APEDA notes the sector's scale remains below export potential, underscoring the need for quality, volume, and organized supply chains.

How Makhana Is Grown in Bihar (Pond & Field Systems) Step-by-Step Process:

A) Pond System (traditional, widespread in Mithila)

1. Site & water depth: Select perennial/stagnant water bodies,1–1.5 m depth.
2. Seed & sowing: For a new pond, sow 80 kg seed/ha; in established ponds, 35 kg/ha suffices as volunteers also germinate. Raise nursery if required, then transplant saplings.
3. Crop management: Maintain water level and control weeds, fertilization is modest in ponds but organic inputs and clean water improve set and seed fill.
4. Harvesting: Divers sweep pond bottoms to collect mature seeds after fruits sink and dehisce labour-intensive, multiple dives per area. Typical seed yield 1.2–1.5 t/ha (up to 1.8–2.2 t/ha in shallow ponds)

B) Field System (FSM; expanding in north/east Bihar)

1. Land prep: Low-lying fields bunded to hold shallow water; puddle as for paddy.
2. Transplanting calendar: First crop can be set out in Feb–Mar, harvested and in Jun–Jul; a second crop (where feasible) can follow Jul–Nov (double-cropping trials by ICAR-RCER).
3. Nutrition: INM packages (e.g.100:60:40 kg N\:P\:K/ha + FYM t/ha) have doubled yields vs ponds in experiments (up to 3.2 t/ha).
4. System advantage Fields allow easier weeding/harvest, better water control, integration with fish or paddy rotations, and often higher productivity.

From Seed to Snack: Post-Harvest Processing—Step-by-Step

Traditional Method (village scale)

1. Cleaning & sun-drying: Wash fresh seed; sun-dry 2–3 hours to 31% moisture. Store 20–25 days, occasionally sprinkling water to keep kernels pliable.
2. Size grading: Sort into 5–7 sieve grades for uniform heating.
3. Pre-heating: Roast in earthen/cast-iron pans at 250–300 °C for 5–6 min to condition to 20% moisture. Temper 48–72 h.
4. Final roast & pop: Re-roast small batches at 290–340 °C for 1.5–2.2 min; crack 5–7 seeds at a

time on a wooden anvil with a mallet the kernel "pops" (lava). Typical pop recovery 35–40% of seed weight.

5. Polish, grade, pack: Rub to whiten, grade into consumer sizes and bag (gunny with liners for distance).

Mechanized method (FPO/MSME scale)

What changes: ICAR-CIPHET's line integrates threshing/cleaning, grading, drying, closed-barrel roasting with thermic oil, and automatic impact popping eliminating hand malting and direct heat exposure.

Why it matters: Cuts total process time from 2–3 days to 20 hours; improves uniformity; safety; and earns ₹50/kg more than manual pop due to quality. Capacity models of 25–30 kg/h (and larger) are in commercial use.

Cluster economics: Contemporary plants (150–300 kg/h) cost roughly ₹0.75–1.75 crore, with ongoing cluster proposals in 'Darbhanga' to support artisans and FPOs.

Markets, Prices, and Policy Signals

Price dynamics: Domestic pop prices roughly doubled over 2020–2024, with volatility around 2022–23 (classic "cobweb" effect) as supply responded to demand spikes.

Exports & branding: Mithila Makhana's GI tag and after G20 visibility nudged interest abroad; APEDA counts 'USA/UK/Australia' among key destinations and estimates export value at 'USD 1.38 million' recently small relative to potential.

Organization gap: Bihar's makhana trade remains largely unorganized (no APMC framework), depressing farm-gate shares and obscuring reliable arrivals/price data—an impediment to scale.

What's next: National discussions on a dedicated Makhana Board (Budget 2025) aim to streamline production, processing, and marketing—especially for export-grade quality.

Summary

* Bihar is India's makhana powerhouse '85–90%' of output, '5 lakh' livelihoods—and area/production have climbed steadily with improved varieties and new field systems.
* Traditional pond cultivation and hand popping still dominate, but 'mechanization' is rapidly improving safety, quality, and throughput.
* GI tagging, FPOs, and cluster investments are strengthening branding and value addition, though 'unorganized marketing' and limited credible data continue to hold the sector back.
* For farmers and MSMEs, the step-by-step practices above and adoption of improved seed, INM in field systems, and modern popping—offer the clearest path to higher yields, better margins, and export-grade quality.

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Health Benefits of Mulberry Plant

Abstract

Mulberry (Morus spp.) is abundant in bioactive compounds such as flavonoids, alkaloids, phenolics, anthocyanins, and dietary fiber, which are responsible for its broad spectrum of health-promoting effects. Various parts of the plant—including its leaves, fruits, roots, and bark—demonstrate antioxidant, antimicrobial, anti-inflammatory, antidiabetic, neuroprotective, cardioprotective, and digestive-supportive activities. Moreover, mulberry contributes to metabolic balance and shows potential in managing chronic illnesses like diabetes, cardiovascular diseases, neurodegenerative disorders, and gastrointestinal problems. With its rich phytochemical content and lack of toxic elements, mulberry is considered a promising candidate for functional foods and nutraceutical development.

Keywords: Mulberry, Health, Benefits, Plant, Compounds

Introduction

Mulberry (*Morus alba*), a rapidly growing deciduous species belonging to the genus *Morus* under the family Moraceae, is extensively cultivated across diverse climates. Mulberry is recognized as a rich reservoir of natural antioxidants such as vitamin C, anthocyanins, polyphenols, and other bioactive nutrients, apart from its role in traditional medicine (Łochyńska, 2015). Additionally, it supplies essential carbohydrates, dietary fibre, minerals, riboflavin, nicotinic acid, and fatty acids. Each part of the mulberry plant is abundant in phytochemicals, including flavonoids, alkaloids, steroids, and terpenoids, which contribute to a wide spectrum of biological activities such as antioxidative, neuroprotective and vasoactive, antihyperlipidemic, antidiabetic, and cytoprotective effects (Jiao *et al*., 2017). More recently, different plant parts have been incorporated into functional foods, nutraceuticals, and cosmetic formulations. However, despite its phytochemical richness and versatile applications, mulberry remains underutilized on an industrial scale due to its high perishability and short harvesting window, limiting its commercial exploitation to specific regions.

Health benefits of mulberry:

Antidiabetic and hypoglycemic effects: Both mulberry leaves and fruits exhibit hypoglycemic activity, largely attributed to the presence of 1-deoxynojirimycin (DNJ), a compound known to inhibit α-glucosidase activity.

Clinical evidence has demonstrated its effectiveness in the management of type 2 diabetes (Ramesh *et al*., 2014). The leaves of *Morus alba* have been incorporated into traditional Chinese medicine for centuries as a therapeutic agent for diabetes prevention and treatment, primarily due to their bioactive constituents that suppress postprandial hyperglycemia following carbohydrate-rich meals (Miyahara *et al*., 2004).

Cardiovascular and lipid-lowering activity: Flavonoids and phenolic constituents present in mulberry have been shown to exert cardioprotective effects. These bioactive compounds contribute to the regulation of blood pressure, reduction of cholesterol levels, and prevention of atherosclerotic plaque formation (Shreelakshmi *et al*., 2021).

Antioxidant and anti-inflammatory potential: Mulberry leaf extracts exhibit the highest antioxidant activity, surpassing petiole, fruit, and stem extracts in DPPH and hydrogen peroxide scavenging assays. In *M. nigra* fruits, anthocyanins such as cyanidin-3-O-glucoside (C3G) and cyanidin-3-O-rutinoside (C3R) have demonstrated anti-inflammatory properties by inhibiting pro-inflammatory cytokines in animal models of xylene-induced ear edema and carrageenan-induced paw edema (Chen *et al*., 2016). Aqueous extracts of M. alba root show strong anti-histaminic and anti-allergic effects by suppressing histamine release and mast cell–mediated responses (Chai et al., 2005).

Neuroprotective properties: Mulberry leaves contain kaempferol derivatives that may inhibit amyloid-β peptide formation, potentially reducing plaque deposition in Alzheimer's disease. Methanolic extracts of mulberry leaves have also demonstrated anti-dopaminergic activity by blocking dopamine (D2) receptors. M. alba fruits provide neuroprotection, with anthocyanins, rutin, and quercetin showing strong neuroprotective and bioactive effects (Zhang et al., 2009).

Gastrointestinal disorders: Mulberry leaves support digestive health through their high dietary fiber, which aids stool bulking and improves digestion (Kadam et al., 2019). Moreover, mulberry leaf extracts have demonstrated hepatoprotective effects; for instance, Hogade *et al*. (2010) observed liver protection in rats treated with carbon tetrachloride following administration of mulberry leaf extract. Mulberry leaves, rich in fibers, minerals, vitamin C, and antioxidants but free from toxic compounds, boost metabolism and offer significant health benefits.

Antimicrobial effects: Chalcomoracin, a phytoalexin found in mulberry leaves, has shown potent antibacterial activity against *S. aureus* (Fukai *et al*., 2005). Similarly, ethanolic extracts of mulberry leaves were found to protect against *Artemia salina* (L.), which induces oral toxicity in mice. Ethanol extracts of M. alba leaves showed strong antimicrobial activity against Gram-negative and Gram-positive bacteria, as well as several fungal species (Ayoola et al., 2011).

Anticancer effects: Although an absolute cure for cancer is not yet available, the antioxidant-rich profile and bioactive compounds of mulberry offer significant potential in reducing cancer risk and progression. Ethanol extracts of mulberry leaves have been shown to selectively eliminate neuroblastoma stem cell-like populations, which play a crucial role in the persistence and aggressiveness of this malignancy. Treatment with 10–40 µg/mL of mulberry leaf extract enhanced cellular differentiation by promoting neurite elongation, reducing clonogenicity, and suppressing sphere formation. These effects were associated with a downregulation of stem cell markers and upregulation of differentiation markers.

Cardiovascular diseases: Flavonoids and phenolic constituents present in mulberry exhibit significant cardioprotective properties (Verma *et al*., 2022). They contribute to the regulation of blood pressure, aid in lowering cholesterol, and play a role in reducing the risk of atherosclerosis. Mulberry leaves have been recognized as a valuable dietary component for cardiovascular health owing to their rich composition of bioactive compounds and minerals. Kadam *et al*. (2019) reported that the high iron (Fe) content in mulberry leaves supports enhanced oxygen transport by stimulating the production of red blood cells.

Skin diseases: Beyond its use as a traditional tea, mulberry leaf extract has also gained attention as a natural ingredient in skincare formulations. It demonstrates notable anti-aging properties and has shown effectiveness in managing acne-prone skin by reducing inflammation and regulating excessive sebum secretion. Owing to its strong anti-tyrosinase activity, mulberry leaf extract is widely recognized for promoting skin lightening and radiance. Tyrosinase is a key enzyme involved in the regulation of melanin biosynthesis, and its inhibition directly influences pigmentation (Sarkhel *et al* 2020).

Conclusion

In conclusion, mulberry is a rich reservoir of bioactive compounds that provide diverse health benefits. Its strong antioxidant, antimicrobial, anti-inflammatory, antidiabetic, neuroprotective, and cardioprotective activities underline its therapeutic potential in managing and preventing chronic disorders. With its high nutritional value and safety profile, mulberry emerges as a promising resource for functional foods, nutraceuticals, and future therapeutic innovations.

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Why Food Security Matters to All of Us

Abstract

This article highlights the importance of global food security and the challenges that threaten it. Food security is not only about survival but about culture, family, and dignity. Despite producing more than enough, millions still go to bed hungry due to inequality, climate change, resource shortages, and conflicts. The article explores the realities, causes, human impacts, and solutions for ensuring everyone has access to safe, nutritious food, while also emphasizing why food security matters for the future of humanity.

Introduction

Food isn't just about survival. It's about family dinners, street-side snacks, festival feasts, and the comfort of a warm meal after a long day. It's woven into our memories, cultures, and identities. Yet, in a world that grows enough to feed everyone, millions still remain hungry. Food security means ensuring that every person, regardless of location or income, has access to safe, nutritious, and affordable food. However, this simple goal is still out of reach.

Challenges of Global Food Security

1. More People, Less Land

The global population is growing fast, but farmland is not. Farmers, especially in Asia and Africa, face pressure to feed growing populations with limited resources.

2. Climate Is Changing Everything

Floods, droughts, and heatwaves are destroying harvests and making farming unpredictable. Crops that once thrived now struggle, and new pests are appearing in unfamiliar regions.

3. Land and Water Are Running Out

Cities expand while forests shrink, reducing fertile farmland. Freshwater resources are also diminishing, even though agriculture consumes most of it.

4. Food Wastage

One-third of all food produced is wasted. Food rots in fields, spoils in transport, or is thrown away in homes, even as millions go hungry.

5. Conflict and Crisis Disrupt Everything

Wars and economic collapses disrupt food supply chains. The Russia–Ukraine conflict sent global grain markets into crisis, affecting import-dependent nations the most.

6. Hunger Isn't Always About Quantity

Even when food is available, it may not be affordable or nutritious. Many families rely on cheap, filling foods lacking essential nutrients, leading to malnutrition and poor health.

Causes Behind Food Insecurity

• Dependence on limited staple crops like wheat, rice, and maize.

• Unsustainable farming methods that harm soil and water.

• Weak infrastructure in developing countries.

• Global inequality—some nations waste food while others starve.

• Changing diets with higher demand for meat and processed foods.

The Human Cost

• Malnutrition in children affects both body and mind.

• Families lose income and face higher medical expenses.

• Communities protest when food prices rise.

• Migration increases as people leave homes in search of food security.

• Over-farming damages land and ecosystems.

What We Can Do Together

• Grow Smarter: Use organic methods, crop rotation, and soil protection.

• Adapt to the Climate: Develop climate-resilient crops and use smart irrigation systems.

• Build Better Systems: Invest in storage and transport to prevent spoilage.

• Stop the Waste: Raise awareness, improve packaging, and redistribute surplus food.

• Work Together: Fair trade, aid, and shared research to stabilize food systems.

• Feed Minds and Bodies: School meal programs and community kitchens.

• Innovate Boldly: Explore plant-based proteins, lab-grown meat, and insect farming.

Why It All Matters

• Healthy people build stronger societies.
• Stable food systems support economies.
• Reducing hunger lowers inequality.
• Sustainable farming protects the planet.
• Less hunger means more peace.

Barriers to Achieving Food Security

• Advanced technology is costly and out of reach for small farmers.

• Limited access to land, water, and credit.

• Weak government support in some regions.

• Resistance to change due to traditional practices.

• Regional differences mean no universal solution.

Conclusion

Food security isn't just a global issue—it's personal. It's about ensuring that no child goes to school hungry, no parent sacrifices meals for their children, and no farmer feels abandoned. The tools and knowledge exist, but what we need most is the will to act, to share, and to care. In the end, food is not just about calories—it is about compassion, dignity, and justice for all.

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Genetically Modified Crops: Transforming Global Agriculture and Shaping the Future of Food Security

Abstract

Genetically modified (GM) crops have emerged as a landmark innovation in agriculture, offering solutions to challenges such as food insecurity, climate change, and nutritional defici0.encies. By integrating desired traits like pest resistance, drought tolerance, and enhanced nutritional value, GM crops are reshaping farming practices worldwide. This article reviews the current status of GM crop cultivation, highlights their economic, social, and environmental benefits, and evaluates the associated risks and controversies. It further explores the future prospects of GM technology in achieving sustainable agriculture and food security. A balanced approach, combining scientific evidence, transparent regulation, and farmer empowerment, will determine the role of GM crops in the decades ahead.

Introduction

Feeding the world's growing population is one of the greatest challenges of the 21st century. By 2050, global food demand is expected to rise by nearly 50%, yet agriculture faces increasing constraints: climate change, shrinking farmland, soil degradation, and the constant threat of pests and diseases. In this backdrop, genetically modified (GM) crops have been introduced as a scientific breakthrough with the potential to revolutionize modern agriculture.

Genetic modification allows scientists to directly alter the DNA of plants to incorporate beneficial traits. Unlike conventional breeding, which is slow and imprecise, genetic engineering provides accuracy, speed, and the ability to transfer genes across unrelated species. Since their commercial introduction in the 1990s, GM crops such as Bt cotton, herbicide-tolerant soybean, and vitamin-enriched rice have attracted both strong advocacy and intense criticism.

Current Growth of GM Crops in Agriculture

Global Trends: Today, GM crops are cultivated in more than 29 countries, with another 40 nations importing GM produce. The United States, Brazil, Argentina, India, and Canada are the leaders, accounting for over 90% of the world's GM crop acreage.

The four primary GM crops dominating global cultivation are:

1. Soybean – engineered for herbicide tolerance.
2. Maize – modified for insect resistance and herbicide tolerance.
3. Cotton – developed for pest resistance.
4. Canola – engineered for herbicide tolerance.

Growth in India

India entered the GM revolution in 2002 with Bt cotton, genetically engineered to resist bollworm attacks. Today, more than 95% of India's cotton fields are planted with Bt varieties, significantly increasing yields while reducing pesticide dependency. However, the approval of GM food crops has been slow. Research is ongoing in rice, brinjal, and mustard, with the DMH-11 hybrid mustard awaiting regulatory clearance.

Benefits of GM Crops

1. Higher Productivity and Yield – GM crops help minimize losses from pests, weeds, and climatic stress, leading to improved yields.
2. Reduced Chemical Use – Insect-resistant GM varieties reduce reliance on chemical pesticides.
3. Enhanced Nutritional Value – Nutritionally improved GM crops address hidden hunger.
4. Tolerance to Environmental Stress – Crops engineered to withstand drought and salinity secure harvests.
5. Economic Benefits for Farmers – Reduced input costs and better yields improve farmer incomes.

Challenges and Concerns

1. Resistance in Pests and Weeds – Continuous use can lead to resistant super-pests and weeds.
2. Loss of Biodiversity – Large-scale monocultures may threaten crop diversity.
3. Health and Safety Concerns – Uncertainty about allergenicity and long-term effects.
4. Socioeconomic Dependence – Seed patents controlled by corporations raise dependency fears.
5. Ethical and Cultural Issues – Opposition due to ethical and religious reasons.

The Future of Agriculture with GM Crops

1. Next-Generation Genetic Engineering – CRISPR-Cas9 enables more precise and affordable gene editing.
2. Climate-Smart Agriculture – Drought- and flood-tolerant crops will aid climate adaptation.
3. Biofortification – Nutritionally enriched staples will reduce malnutrition.
4. Sustainable Farming Integration – GM crops can complement eco-friendly practices.
5. Policy and Global Acceptance – Transparent regulations and farmer participation are essential.

Conclusion

Genetically modified crops represent a double-edged sword in modern agriculture. On one hand, they provide solutions to food insecurity, climate stress, and malnutrition while enhancing farmer incomes and reducing chemical dependency. On the other hand, they pose challenges relating to biodiversity, resistance development, ethical debates, and farmer dependency.

The future of GM crops lies not in outright acceptance or rejection but in carefully managed, science-based adoption. With responsible regulation, inclusive farmer participation, and a focus on sustainability, GM crops can become a cornerstone of global food security in the 21st century.

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Integrated Pest Management for Paddy in Godavari Delta

Introduction

Integrated Pest Management (IPM) is an environmentally friendly approach to managing pests in paddy cultivation, especially significant in the Godavari Delta, a critical rice-growing region in India. The method combines cultural, biological, mechanical, and chemical tools to control pest populations economically and sustainably while minimizing harm to the environment.

The Godavari Delta, with its fertile soils and extensive irrigation systems, supports high paddy productivity but faces challenges from pests such as brown planthopper (Nilaparvata lugens), yellow stem borer (Scirpophaga incertulas), leaf folder (Cnaphalocrocis medinalis), and gall midge (Orseolia oryzae). Excessive chemical pesticide use has led to resistance, pest resurgence, and ecological imbalance, highlighting the need for IPM.

Cultural practices form the first line of defense in IPM. Adjusting sowing times, maintaining recommended plant spacing, proper nutrient and water management, and removing crop residues help disrupt pest life cycles. Synchronized planting and crop rotation with legumes further reduce pest pressure and enhance soil fertility. Biological control is a key component, relying on natural predators and parasitoids. Spiders, mirid bugs, and dragonflies prey on harmful pests, while Trichogramma egg parasitoids and Bacillus thuringiensis (Bt) formulations suppress stem borers and leaf folders. Conserving these beneficial organisms ensures long-term pest suppression without chemical inputs.

Mechanical and physical controls include hand-picking egg masses, installing pheromone traps for stem borer monitoring, and using light traps to detect moth activity. These methods are simple, cost-effective, and reduce pest populations at early stages. Chemical control should be used only as a last resort, based on economic threshold levels (ETL). Farmers should select specific insecticides that target pests while sparing beneficial organisms. Proper timing, dosage, and application methods reduce environmental impact and pesticide residues.

Farmer education and community participation are essential for successful IPM implementation. Farmer Field Schools (FFS) and training sessions help disseminate knowledge, while collective actions like synchronized planting and shared pest surveillance strengthen pest management at the community level.

Adoption of IPM in the Godavari Delta has shown reduced pesticide costs, improved yields, and preserved ecological balance. By protecting soil health and water resources, IPM supports long-term agricultural sustainability.

Table 1: Key Components of IPM for Paddy in Godavari Delta

Component	Description
Cultural Practices	Adjust sowing dates, maintain spacing, and remove residues to reduce pest habitats.
Biological Control	Use natural predators (spiders, mirid bugs) and parasitoids (Trichogramma) to suppress pests.
Mechanical Control	Use light and pheromone traps, and hand-pick egg masses.
Chemical Control	Apply selective insecticides based on ETL to minimize ecological damage.

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Revolutionizing the Fields: AI Cultivates a New Era for Indian Agriculture

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Government and startups roll out smart tools and advisory systems nationwide

The agricultural sector in India is being intensely industrially challenged by factors of unpredictable weather, rising costs of production and a massive shortage of labour despite the largely dependable nature of agriculture as the foundation of livelihood of a large proportion of the populace. As a reaction to these pressures, we are witnessing the emergence of artificial intelligence and data analytics as the key tools that reduce the severity of such adversities. Researchers and pundits argue that diseases and technologies driven by AI in agriculture are estimated to have a world-wide scale ranging between US1.7 billion in 2023 and a predicted US 4.7 billion in 2028**,** Offering farmers real-time information about the meteorological conditions, soil properties and plant health. Government institutions and individual innovators in India are rolling out new platforms -including satellite-enabled yield prediction systems and smartphone-enabled crop-advisory platforms -aimed at improving agricultural productivity and sustainability.

Government Initiatives

A recent Digital Agriculture Mission by the Union government is aimed at entrenching artificial intelligence and data analytics in the agricultural practice at the national level. The initiative was legislated in September 2024 and has allocated a budget of ₹2,817crore to create a digital community infrastructure in which the farming community makes up. The backbone of this architecture is the AgriStack a digital registry that gives each farmer a unique identifier associated with a set of land and livestock footprint, and also creates geo-tagged cartographic representations of fields and type of crops (pib.gov.in). The proposal envisions that of a three-year period, about 1.1 crore individual farmer IDs will be granted; and amenity of an entire digital crop survey, with a scope of 400 districts during the 202425 rounds. As a result, a broad database of all the registered farmers and their areas is enshrined and the main goal is to enhance effectiveness and transparency of subsidy scheme, issuance of loans and insurance schemes.

Besides, the administration is using artificial-intelligence-based advisory tools to help in the day-to-day agricultural activities. Indicatively, a hosting voice chatbot such as the Kisan e-Mitra can reply to queries on topics like crop plans and the PM-Kisan subsidy in eleven regional dialects thus fulfilling more than twenty thousand queries daily among farmers.

Also, the National Pest Surveillance System uses AI/ML to identify pest and disease threats on field photographs of up to 61 crops, so that over ten thousand extension workers can make early warnings to farmers.At the same time, with the support of fiscal incentives through the Sub-Mission on Agricultural Mechanization and a new bundle named Namo Drone Didi, authorities are promoting the use and adoption of drone technologies in agriculture in terms of application and monitoring. With these mechanisms, many farmer groups and women cooperatives can receive a state subsidy, usually half to three-quarters the price of drones bought out. The idea behind such interventions is to introduce new sophisticated tools to the traditional farming process, such as accurate sensors, flying drones, and Internet of Things systems.

Private-Sector Innovations

The current state of the agritech startup ecosystem in India is characterized by a propagation of solutions grounded in artificial intelligence (AI). Applications like AgroStar and DeHaat empower farmers by providing better access to quality inputs and offering agronomic advice tailored to their local language. Other ventures focus on data analytics. Bengaluru-based startups CropIn and Fasal utilize sensor networks and AI algorithms to deliver precise irrigation schedules and yield simulations based on meteorological, soil, and satellite data. Another significant trend is the emergence of digital marketplaces that leverage advanced technology. New services such as Ninjacart and WayCool establish direct connections between farmers and buyers, eliminating intermediaries and ensuring that farmers receive more favorable prices. Startups with specialized applications are employing computer vision techniques and machine learning (ML) to enhance the quality of produce. AgNext, based in Punjab, has developed vision systems capable of grading chili peppers and detecting defects directly in the field. Similarly, Intello Labs, located in Karnataka, uses AI to assess the quality of fruits and vegetables and reduce spoilage, enabling farmers to achieve higher prices. Additionally, there has been a rise in fintech activity, including digital underwriting by Jai Kisan, which provides rapid loans through technology, and "buy-now-pay-later" services that enable farmers to purchase superior seeds and equipment, thus facilitating investment in quality inventories. When all these developments are considered together, modern farming implements are becoming increasingly affordable for Indian farmers.

Field Deployments and Pilots

Artificial intelligence in agriculture can be developed as evidenced by pilot projects. The state of Telangana has the Saagu Baagu (Prosperity) program, a partnership between government and industry which used AI-based advisory systems and a WhatsApp chatbot in the Telugu language to assist about 7 000 chili farmers in the Kuramam district. In three consecutive years of growth, the participants grew their yield by an average of about 21 3/4 and multiplied their net earnings by a factor close to two with the income per season standing at approximately US 800/acre. Reduction in pesticide use (9 percent) and fertilizer usage (5 percent) were also factors of the trial. Improved grading process added price value of between 8-10%. A similar program has been in Maharashtra to the sugarcane farms of Baramati. The initiative put up AI-enhanced weather sensors and soil sensors that sent information to the Agripilot.ai program. New daily alerts included the name of either water or spray pesticide, including real-time sensor values using sensors and satellite data, which allowed farmers to modify input application metrics to ensure superior-quality sugarcane. These examples help visualize the idea that the perspective of the support of language, using a combination of data analytics and remote sensing, but aimed on a local scale, can be satisfactory in adapting AI technologies to local needs of the Indian farming system.

Promise and Challenges

Conceptually, machine learning and artificial intelligence have the ability to directly improve operational efficiency gradually in small farms. Sensors which detect crop stress through drone or satellite images enable effective control of pesticides or irrigation hence low running costs and fewer environmental effects. Modern neural-network algorithms can identify plant diseases with great degrees of accuracy and makes it possible to conduct timely remedial measures before the outbreaks rapidly spread. The potential gains are immense; even 10-20 percent increase in yield/ input savings would significantly improve the income and fortitude of the farmers. In fact, empirical data conducted on pilot programs earlier prove that the net profits of participating farmers are great, which can be shown with regard to the SaaguBaagu chili example.

However, analysts warn that the implementation is likely to be disproportionate. Significant challenges arise from infrastructural shortages and insufficient digital literacy.

According to a recent report compiled by MediaNama, it is estimated that only about 2% of Indian farmers currently utilize the potential of mobile applications or IoT services in their agricultural activities. Hundreds of millions of smallholders still lack access to smartphones or reliable internet services, and many are unable to obtain a digital identification record due to the absence of Aadhaar cards or unclear land ownership rights. Stakeholder issues have become even more pronounced: opponents argue that an engaging AgriStack database could infringe on farmer confidentiality and necessitates the building of trust to alleviate concerns about surveillance. Bridging such inequalities will require increased connectivity in rural communities, capacity building in farming, and high data protection standards. These challenges, as noted in one analytical study, can only be addressed through a collaborative effort among government, industry, and academia.

Despite these challenges, India's initiatives, through innovative digital projects in New Delhi and dynamic start-ups in rural towns, indicate a growing momentum. Should the promise of artificial intelligence be fully realized, even modest efficiency gains could enable Indian farmers to achieve greater production and income. The coming years will evaluate the pace at which these technologies grow for the millions of small farms.

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Soil Salinity: A Silent Threat to Agriculture and How We Can Overcome It

Introduction

Imagine walking across a farm on a bright sunny day. Instead of thriving green crops, you notice leaves turning yellow, stunted plants struggling to grow, and strange white crusts on the soil's surface that almost look like frost. This is not the work of drought, frost, or pests. The silent culprit is **salt**, and its slow invasion of farmland is one of the greatest hidden challenges to global agriculture today.

Soil salinity—often caused by improper irrigation, poor drainage, or natural processes—is a creeping problem that is reducing productivity across millions of hectares of land. According to the **Food and Agriculture Organization (FAO)**, nearly **20% of the world's irrigated farmland is affected by salinity**, and every single day around **2,000 hectares of productive land are lost** to this issue. In India alone, over **7 million hectares of land suffer from soil salinity**, threatening food security and farmer livelihoods.

The tragedy is that much of this damage is **man-made**. Yet the good news is that with better farming practices, technology, and sustainable land management, soil salinity can be reduced, controlled, and even reversed.

Why Soil Salinity is a Problem?

Soil salinity occurs when water-soluble salts accumulate in the soil at levels high enough to reduce crop growth. These salts include **sodium, calcium, magnesium, and chlorides**, which can come from irrigation water, fertilizers, or natural mineral deposits. While plants need small amounts of some salts for growth, excess salt becomes toxic.

1. Impact on Plants

- **Water Stress**: Normally, plant roots absorb water from the soil. But in salty soils, the process reverses—water is pulled out of the roots instead. Plants wilt even when the soil looks moist.
- **Nutrient Imbalance**: Excess salts interfere with the absorption of essential nutrients like potassium and nitrogen, leading to nutrient deficiencies.
- **Physical Damage**: Sodium in particular damages soil structure, making it hard and compact like concrete. This reduces water infiltration and root penetration.

2. Impact on Soil

- Reduced fertility and poor aeration.
- Crust formation that hinders seed germination.
- Toxic levels of sodium carbonate (alkalinity) that degrade organic matter.

3. Impact on Farmers and Food Security

- Lower crop yields and income losses.
- Abandonment of farmland due to unproductivity.
- Increased cost of cultivation as farmers spend more on fertilizers, soil amendments, and alternative irrigation.

Sources of Soil Salinity

While some soils are naturally saline due to their geological origins, human activities are the main reason the crisis has intensified in recent decades. Irrigation is one of the biggest contributors, as even freshwater contains small amounts of dissolved salts. With repeated irrigation cycles, the water evaporates but the salts remain in the soil, causing a gradual buildup. Poor drainage further aggravates the issue; in areas with heavy irrigation and inadequate drainage systems, water stagnates in the root zone, preventing salts from being leached away. Overuse of fertilizers is another major factor, since most fertilizers are chemically salts, and applying them excessively not only wastes resources but also accelerates salinity. Deforestation and unscientific land management practices make the situation worse, as the removal of trees lowers the natural control of the water table, allowing saline groundwater to rise and deposit salts closer to the surface. Finally, climate plays a significant role, especially in arid and semi-arid regions where high evaporation rates and low rainfall increase the concentration of salts, leaving soils degraded and unsuitable for healthy crop growth.

Global and Indian Scenario

- **Globally**: Nearly **1 billion hectares** of land worldwide suffer from soil salinity and sodicity, with hotspots in Australia, Central Asia, the Middle East, North Africa, and the Indo-Gangetic plains of South Asia.

- **India**: The Indo-Gangetic region, Gujarat, Rajasthan, Uttar Pradesh, Punjab, and coastal areas are worst affected. Here, saline groundwater, excessive irrigation for crops like rice and wheat, and poor drainage systems intensify the problem.

For example, in Gujarat’s Kutch region, large tracts of fertile land have been rendered unproductive due to salinity. Similarly, in Punjab and Haryana, heavy use of canal irrigation without proper drainage has worsened the crisis.

Solutions and Management Strategies

The good news is that soil salinity is manageable if addressed early with the right techniques. Solutions involve a mix of **agronomic, technological, and ecological approaches**.

1. Smarter Irrigation

- **Drip and Sprinkler Systems**: Deliver water directly to roots, reducing wastage and salt buildup.

- **Scheduling**: Avoid over-irrigation and waterlogging.

- **Freshwater flushing**: Occasional application of freshwater helps wash away excess salts.

2. Soil Amendments

- **Leaching**: Applying extra clean water to wash salts deeper into the soil profile.

- **Gypsum**: Adds calcium which replaces sodium, improving soil structure and permeability.
- **Organic Matter**: Compost and manure improve soil texture and microbial activity, making soils more resilient.

3. Crop Management

- **Salt-tolerant Crops**: Growing varieties like barley, quinoa, sorghum, mustard, and certain millets that withstand high salinity.
- **Crop Rotation and Cover Crops**: Helps improve soil fertility and reduce salt concentration.

4. Agroforestry and Biodrainage

Planting trees like **Eucalyptus** and **Acacia** can lower the water table naturally, reducing the upward movement of salts.

5. Policy and Institutional Support

- Government programs can support farmers with **training, subsidies for drip irrigation, and gypsum distribution schemes**.
- Research institutions must develop **salt-tolerant seed varieties** and promote farmer awareness campaigns.

Future Outlook: Sustainable Soil Management

With climate change increasing evaporation rates and reducing the availability of freshwater, soil salinity is projected to expand rapidly unless urgent measures are taken. Addressing this challenge requires a sustainable, multi-dimensional approach. Traditional knowledge such as the use of organic amendments, mixed cropping, and water harvesting must be integrated with modern technologies like improved irrigation methods and biotechnology. At the same time, precision agriculture offers powerful solutions through the use of remote sensing, GIS, and soil sensors that allow farmers to monitor salinity levels closely and apply water or inputs only where necessary. Community participation is equally important, as collective action in managing water resources and restoring soil health can achieve far greater results than isolated efforts. Finally, strong policy commitment is critical, with governments needing to provide long-term support in the form of research investments, subsidies for sustainable farming practices, and awareness programs that empower farmers to protect their soils.

Conclusion

Soil is not just “dirt.” It is the living foundation of agriculture, holding the key to food security, farmer livelihoods, and environmental sustainability. Soil salinity may be a silent destroyer, but it is not unstoppable. With smarter irrigation, soil amendments, salt-tolerant crops, and sustainable land management, we can reclaim degraded lands and secure future harvests. Every hectare saved from salinity is a step toward ensuring that future generations will inherit fertile, productive land. The challenge is real, but so is the hope—because every small step farmers, scientists, and policymakers take today can keep our fields alive and thriving tomorrow.

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PROMISING PROSPECTS FOR YOUTH IN AGRICULTURAL EDUCATION

Abstract

Agriculture remains the backbone of the Indian economy, contributing 17% to GDP and employing over 60% of the population. With 73 universities and nearly 900 colleges, India offers vast opportunities in agricultural education. This chapter examines career pathways for youth through higher studies, research, agribusiness, and government services, while also highlighting entrepreneurial ventures in food processing, organic farming, and agri-tech startups. Case studies of young innovators demonstrate how education and technology are reshaping traditional farming into profitable, sustainable enterprises. The study concludes that agricultural education provides not only employment but also avenues for entrepreneurship and nation-building, ensuring a bright future for India's youth.
Keywords: Agriculture, Entrepreneur, Eployement, Education.

Introduction

Agriculture is the foundation of human civilization and the backbone of the Indian economy. It contributes about 17 percent to India's Gross Domestic Product (GDP) and provides employment to more than 60 percent of the population. Beyond its economic value, agriculture ensures food and nutritional security, sustains rural livelihoods, and contributes nearly one-fourth of the national income. Because of this multifaceted importance, agriculture is often regarded as the "source of life" for the nation.

In recent decades, the agricultural sector has undergone a process of transformation. With the integration of science, technology, and education, agriculture is no longer limited to traditional farming. It is evolving into a knowledge-driven, innovation-based sector that offers young people abundant opportunities for career growth, entrepreneurship, and nation-building. This chapter explores the scope, pathways, and prospects for youth in agricultural education.

Agricultural Education in India

India has built a strong institutional network for agricultural education, which serves as the foundation for research, training, and extension services. Presently, the country has **73** agricultural universities, making it one of the largest agricultural education systems in the world.

Among the states, Uttar Pradesh stands out with the highest number of agricultural universities. These include:

- Sam Higginbottom University of Agriculture, Technology and Sciences (Deemed University), Prayagraj
- Rani Lakshmibai Central Agricultural University, Jhansi
- Five state universities, such as Chandra Shekhar Azad University (Kanpur), Acharya Narendra Dev University (Faizabad), Sardar Vallabhbhai Patel University (Meerut), Banda University (Banda), and Mahatma Buddha University (Kushinagar).

Alongside these universities, there are nearly 892 colleges across India offering agricultural courses. These institutions provide flexible learning modes: full-time, part-time, distance education, online, and virtual classrooms. This accessibility has expanded the reach of agricultural education to both rural and urban students, ensuring that knowledge and innovation are not confined to metropolitan centers.

Pathways to a Career in Agriculture

Undergraduate and Postgraduate Studies

Students interested in agriculture typically begin after completing their Class 12 education in science streams. Popular undergraduate options include:

- B.Sc. (Agriculture)
- B.Sc. (Hons) Agriculture
- Specialized degrees in Horticulture, Veterinary Science, Agricultural Engineering, Forestry, Food Science, and Home Science

At the postgraduate level, students may pursue M.Sc. or Ph.D. programs, which open opportunities in research, teaching, and high-level administrative positions.

Professional Roles

Graduates and postgraduates in agriculture can choose from a wide range of professional roles:

- **Research & Academia**: Agricultural Scientist, Plant Geneticist, Food Microbiologist, Soil Surveyor, and University Faculty.
- **Industry & Agribusiness**: Farm Manager, Fertilizer Sales Representative, Crop Specialist, and Agricultural Engineer.
- **Public Sector & Banking**: Agricultural Extension Officer, Rural Development Officer, and Field Officer in banks like the State Bank of India (SBI) or Reserve Bank of India (RBI).
- **ICAR Institutes**: Opportunities in 43 research institutes, 20 national research centres, and 731 Krishi Vigyan Kendras (KVKs) provide scope for applied research and rural outreach.

Entrepreneurship in Agriculture

Agriculture today is not only about jobs but also about entrepreneurial innovation. Young graduates can establish their own ventures in:

- Food Processing & Value Addition
- Agro-based Industries
- Dairy and Poultry Farming
- Agro-Machinery Development
- Water Resource Management
- Agro-retail and Input Supply

With the government promoting Startup India, Atmanirbhar Bharat, and specific schemes for Agri-entrepreneurs, the sector has become a launchpad for rural transformation. NGOs and private companies also partner with youth-led agribusinesses, amplifying their reach and impact.

Employment Trends and Opportunities

Nearly 70 percent of India's population depends on agriculture for livelihood. Yet, the number of trained agricultural graduates remains relatively low compared to the employment potential. This gap creates a favorable environment for educated youth, as competition is less intense than in many other fields.

The sector offers opportunities in:

- **Traditional branches**: Horticulture, Poultry, Plant Science, Soil Science, Food Processing, and Animal Husbandry
- **Emerging branches**: Agribusiness Management, Climate-Smart Agriculture, Precision Farming, Biotechnology, and Sustainable Development

Moreover, government bodies such as the Union Public Service Commission (UPSC) and the Agricultural Scientists Recruitment Board (ASRB) conduct regular recruitment examinations, ensuring stable career opportunities for those with advanced qualifications.

The Future of Agricultural Education

The future of agriculture in India is undeniably bright, provided it is powered by education and innovation. Global challenges such as climate change, food security, and sustainable resource use require a new generation of scientists, engineers, and entrepreneurs who can adapt modern solutions to local contexts.

For youth, agricultural education offers more than a career—it provides an opportunity to become part of the nation's development story. By choosing this field, students can play critical roles in:

- Enhancing food security
- Improving rural livelihoods
- Advancing technology-driven farming
- Contributing to national and global sustainability goals

Conclusion

Agriculture is more than a profession; it is a commitment to society and the nation. The sector combines tradition with innovation, providing scope for research, entrepreneurship, and policy-making. With robust institutional support, diverse career paths, and growing demand for professionals, agricultural education stands as one of the most promising prospects for India's youth. By engaging in agricultural studies, young people can become scientists, innovators, entrepreneurs, and leaders who not only secure their personal futures but also strengthen the backbone of India's economy.

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From PCA to t-SNE and UMAP: A Unified Evaluation of Linear and Nonlinear Dimensionality Reduction Techniques for Clustering

ABSTRACT

Dimensionality reduction combined with clustering offers a systematic way to uncover structure in high-dimensional agricultural data, where numerous correlated features often lead to overfitting and inefficiency. The study compares Principal Component Analysis (PCA), t-distributed Stochastic Neighbor Embedding (t-SNE), and Uniform Manifold Approximation and Projection (UMAP) in terms of visualization, neighbourhood preservation, and cluster separability, translating their trade-offs into practical guidance for downstream applications. A synthetic benchmark data set is used to produce 2D and 3D embeddings of PCA, t-SNE and UMAP, apply KMeans clustering and evaluates trustworthiness, silhouette scores, and k-nearest-Neighbor (kNN) overlap across multiple seeds to assess stability and structure preservation. In 2D, nonlinear methods recover manifold structures which otherwise PCA collapses. UMAP provides clear, cluster-aware layouts, while t-SNE achieves strong local neighbourhood fidelity with less reliable global geometry. In 3D, PCA achieves the highest cluster separation (silhouette ≈ 0.84), UMAP maintains uniformly high trustworthiness (≈ 0.998) with moderate silhouette values (≈ 0.14 – 0.26), and t-SNE delivers high kNN overlap (≈ 0.85) but low silhouette (≈ 0.11), capturing local detail without cohesive global partitions. Metrics remain stable across seeds, confirming reproducibility under the chosen preprocessing and parameters. Each method has distinct limitations. PCA's linearity and sensitivity to scaling and outliers restrict its ability to capture nonlinear structures. t-SNE is computationally expensive, sensitive to hyperparameters, and distorts global geometry. UMAP, while scalable, is parameter - dependent and requires careful hyperparameter tuning. Overall, no single method dominates. PCA is effective for fast, interpretable global structure and denoising, t-SNE excels in revealing fine-grained clusters in small to medium datasets and UMAP offers scalable embeddings that balance local fidelity with global organization, particularly in 3D. Integrating dimensionality reduction with clustering enhances separability, stability, and efficiency, motivating future validation on real agricultural datasets and systematic evaluation of clustering tasks.

Keywords: Nonlinear data, Dimensionality reduction, Cluster, PCA, t-SNE, UMAP

Introduction

High-dimensional data refers to datasets with an exceptionally large number of variables or features relative to the number of observations, such as thousands of sensor readings, spectral bands, image pixels, genomic markers, or time-stamped measurements per plot or animal. Its core challenge is that conventional models can overfit, become unstable, or computationally infeasible, requiring specialized methods like feature selection and dimensionality reduction to extract robust signals. In agriculture, high-dimensional data is increasingly central to precision farming, yield prediction, disease and stress detection, resource optimization, phenotyping, genomics, and supply chains, enabling more accurate decisions on inputs, risk, and sustainability across scales from plant to market.

Reducing dimensionality helps by compressing many correlated or noisy variables into a smaller set of informative features that preserve essential structure, which improves model accuracy, stability, interpretability, and computational efficiency. In practice, this mitigates overfitting, eases visualization, speeds training and inference, and often boosts downstream prediction and decision-making across tasks like phenotyping, disease detection, and yield modeling.

Dimensionality reduction methods (e.g., PCA and its variants) and sparse modeling are commonly used to project many correlated signals into a compact set of informative components for downstream prediction and interpretation.

Clustering

Clustering is an unsupervised machine learning technique that groups unlabelled data points into sets (clusters) such that points in the same group are more similar to each other than to those in other groups, based on a defined similarity or distance metric. Each group is typically assigned a cluster ID, which can then be used to simplify analysis, segment populations, or detect patterns without predefined labels. Dimensionality reduction and clustering reinforce each other, reducing to a compact, rich space that makes clusters more separable, stable, and meaningful. Along with this, clustering can also guide which features to keep by grouping redundant variables. In agriculture, this pairing improves grouping of fields, plants, or pixels for management zones, stress detection, and genotype–environment analysis with faster, more robust pipelines.

Clustering algorithms range from intuitive, simple algorithms to progressively more flexible models. Centroid or partitioning methods such as k-means form k groups by minimizing within-cluster distances to a centroid, they are computationally efficient but assume compact, similarly sized clusters and require choosing k in advance. Commonly used distance metrics are Euclidean or Manhattan for numeric features, cosine for directional data and learned embeddings for mixed data types. Density-based methods like DBSCAN, OPTICS, and HDBSCAN instead define clusters as dense regions separated by sparser areas, naturally handling arbitrary shapes and outliers without predefining k. Hierarchical approaches (agglomerative or divisive) build a tree of merges or splits, revealing multi-scale structure and allowing the number of clusters to be selected afterward via a dendrogram cut. Finally, model-based techniques such as Gaussian mixture models (GMMs) assume data arise from a mixture of distributions and provide soft, probabilistic memberships, effectively capturing elliptical cluster geometries.

Principal Component Analysis (PCA) is a linear technique that transforms a set of possibly correlated variables into a smaller set of uncorrelated variables called principal components, ordered so the first few capture most of the variance in the data. For dimensionality reduction, PCA projects high-dimensional data onto these top components, compressing redundancy and noise while retaining the dominant structure that matters for modeling and visualization. For clustering, PCA acts as a powerful preprocessing step as it stabilizes distances, remove multicollinearity, and sharpen separability in a low-dimensional space. Algorithms like k-means, Gaussian Mixture Models, and density-based methods produce more coherent, stable clusters with faster computation and clearer interpretation.

PCA has several drawbacks. It assumes linear relationships, so it can miss nonlinear structure and curved manifolds in data, leading to suboptimal representations when relationships are complex. Principle components are linear combination of original variables making it hard to interpret. PCA is sensitive to feature scaling and units, without careful standardization components bias toward high-variance variables, yielding misleading directions. Reducing dimensions inevitably risks information loss, choosing too few components can discard task-relevant information, while too many can negate benefits and even invite overfitting. PCA is not robust to outliers and missing data and anomalies can rotate components substantially, and imputation or robust variants are often required. Computational cost can be high for large, wide datasets since eigen decomposition scales poorly with the number of features. PCA also assumes continuous variables and struggles with mixed or categorical data unless transformed (e.g., one-hot), which can inflate dimensionality and sparsity. Finally, components can drift across datasets or seasons, reducing stability and comparability unless the transform is fixed and applied consistently across folds and time.

t-SNE and UMAP are nonlinear dimensionality reduction methods designed to embed complex, high-dimensional data into low-dimensional spaces (typically 2D/3D) while preserving neighbourhood structure, making clusters and manifolds easier to visualize and separate. Compared to linear PCA, they capture curved, nonlinear relationships, often revealing fine-grained groupings that are otherwise hidden, which is especially useful before or alongside clustering.

t-SNE stands for t-distributed Stochastic Neighbour Embedding is a nonlinear dimensionality reduction method primarily used to visualize high-dimensional data in two or three dimensions by preserving local neighbourhood relationships. It models “who is close to whom” in the original space and tries to recreate that neighbourhood map in the low-dimensional plane, emphasizing local structure over exact global distances. At a high level, it converts pairwise similarities between points in the original space into probabilities, then learns a low-dimensional embedding whose pairwise probabilities match, so nearby points stay close and dissimilar points move apart for clear, cluster-like layouts.

UMAP stands for Uniform Manifold Approximation and Projection is a nonlinear dimensionality reduction method that learns a low-dimensional representation (often 2D or 3D) of high-dimensional data by preserving the data’s neighbourhood structure on an underlying manifold. In simple terms, it builds a graph of nearest neighbours in the original space, then optimizes a low-dimensional layout whose connections mirror that graph, revealing clusters and patterns that are hard to see in many dimensions. Many real datasets lie on a curved, lower-dimensional surface (manifold) embedded in a high-dimensional space, UMAP tries to uncover that surface and lay it out in 2D/3D while keeping nearby points close . Similar to t-SNE it also focuses on who is close to whom. UMAP retains local structure and often maintains a reasonable sense of global arrangement.

Table 1 Comparison between linear and nonlinear dimension reduction techniques

Method	Strength	Weakness
PCA	Fast, simple, and deterministic; scales well to large datasets via matrix decompositions; highly interpretable components and retained global structure.	Limited to linear relations; can miss nonlinear manifolds; sensitive to scaling; may need many components to capture structure.
t-SNE	Excellent at revealing tight local clusters and microstructure; captures complex nonlinear neighbourhoods; widely used for exploratory visualization.	Computationally intensive; sensitive to hyperparameters and random seeds; distorts global geometry and inter-cluster distances.
UMAP	Fast and scalable; preserves local structure with better global continuity than t-SNE in many cases; flexible metrics and useful for >2D embeddings.	Stochastic and parameter-sensitive; distances in embedding not strictly metric-faithful; interpretability can be challenging.

Limitations of nonlinear dimension reduction methods

t-SNE has notable limitations. It only preserves local neighbourhoods, so global geometry is often distorted. Distances and cluster sizes in the map should not be taken literally. It is computationally heavy for large datasets and, despite approximations, scales worse than linear reducers. The results are extremely sensitive to hyperparameters like perplexity, learning rate, initialization, and iterations, making reproducibility and interpretation difficult. Stochastic optimization introduces variability at each iteration. Fine details shift unless seeds and settings are tightly controlled. It is predominantly a visualization tool and can harm downstream modeling if used as a generic preprocessor. Adding new points typically requires refitting. Attraction–repulsion balance can create artificial gaps or overly compact clusters and outcomes depend strongly on metric choice and feature scaling, hence, poor preprocessing can yield misleading groupings.

Building on the limitations of t-SNE, UMAP shares several caveats. Embeddings are sensitive to hyperparameters like n_neighbors, min_dist, the distance metric, and the random seed, so different choices can materially alter cluster shapes, separations, and overall layout. Although it often preserves global continuity better than t-SNE, it remains primarily exploratory and can warp distances and areas, meaning inter-cluster distances and sizes should not be read literally. Its k-nearest neighbour graph can bias results depending on sampling density, noise, and the chosen k, causing sparse or imbalanced regions to split or merge unpredictably. Outcomes depend heavily on preprocessing choices, standardization, metric selection (e.g., Euclidean vs. cosine), and optional PCA denoising. Mismatches to data geometry can mask true structure. Reproducibility is challenging because small changes in seed, subsampling, or data order can shift embeddings. Stability checks across seeds and subsamples are essential. While UMAP can provide a transformation for new points, out-of-sample embeddings may drift if the new data distribution shifts. Due to this it is necessary to update the fit. Finally, aggressive settings (small n_neighbors, low min_dist) can over-segment continuous manifolds into many tight clusters, whereas conservative settings can over-smooth and hide meaningful substructure, making careful, dataset-specific tuning indispensable.

Visual representation of these techniques

Synthetic benchmark dataset (N=600, D=100) was formed by mixing Swiss-roll, two-moons and concentric-circles manifolds (200 data points each) and nonlinearly expanding them (polynomial, RBF, trigonometric features). Ground-truth has three clusters used for clustering diagnostics.

PCA collapsed the nonlinear manifolds, producing substantial overlap between clusters; although PCA preserves global variance, it is unsuitable here for revealing nonlinear cluster structure. In conclusion it can be said that UMAP gives the clearest, most cluster-aware 2D layout while t-SNE shows tight local structure and preserves the nonlinear ring/spiral shape. PCA fails to unwrap the nonlinear manifolds although it retains a global linear projection that mixes clusters.

Table 2 Comparison metrics across various techniques

Method	Trustworthiness	Silhouette	KNN Overlap
UMAP 3D	0.998	0.14 - 0.26	0.74
t-SNE 3D	0.997	0.106	0.846
PCA 3D	0.997	0.837	0.809

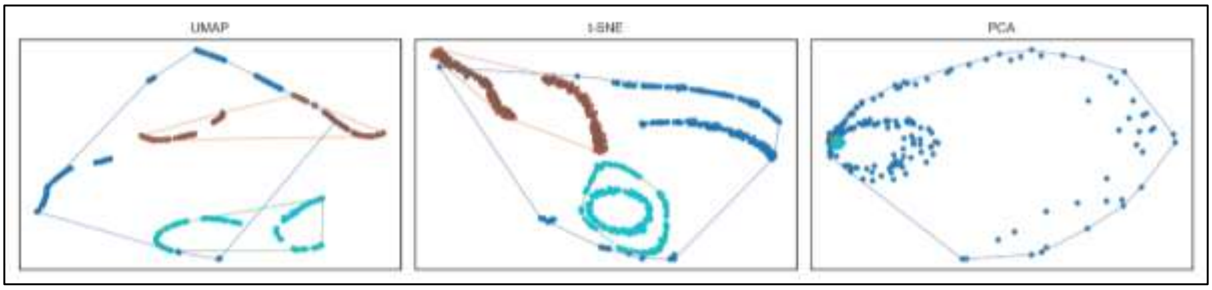

Figure 1 2D visualization of UMAP, t-SNE and PCA

The nonlinear dataset was embedded using UMAP, t-SNE and PCA for 2-D visualization. UMAP produced the clearest separation of the three manifold-derived clusters, preserving local topology while separating clusters into distinct regions. t-SNE did an excellent job preserving local neighbourhoods i.e., points that belong together are grouped tightly, though its global arrangement is arbitrary.

The metrics appear very consistent across seeds since the numbers are nearly identical per-method, which is good. It implies that the embeddings are stable given the chosen parameters. Slight variation in UMAP silhouette across seeds (0.14 → 0.26) suggests mild stochastic variability for cluster boundaries whereas t-SNE and PCA were extremely stable here.

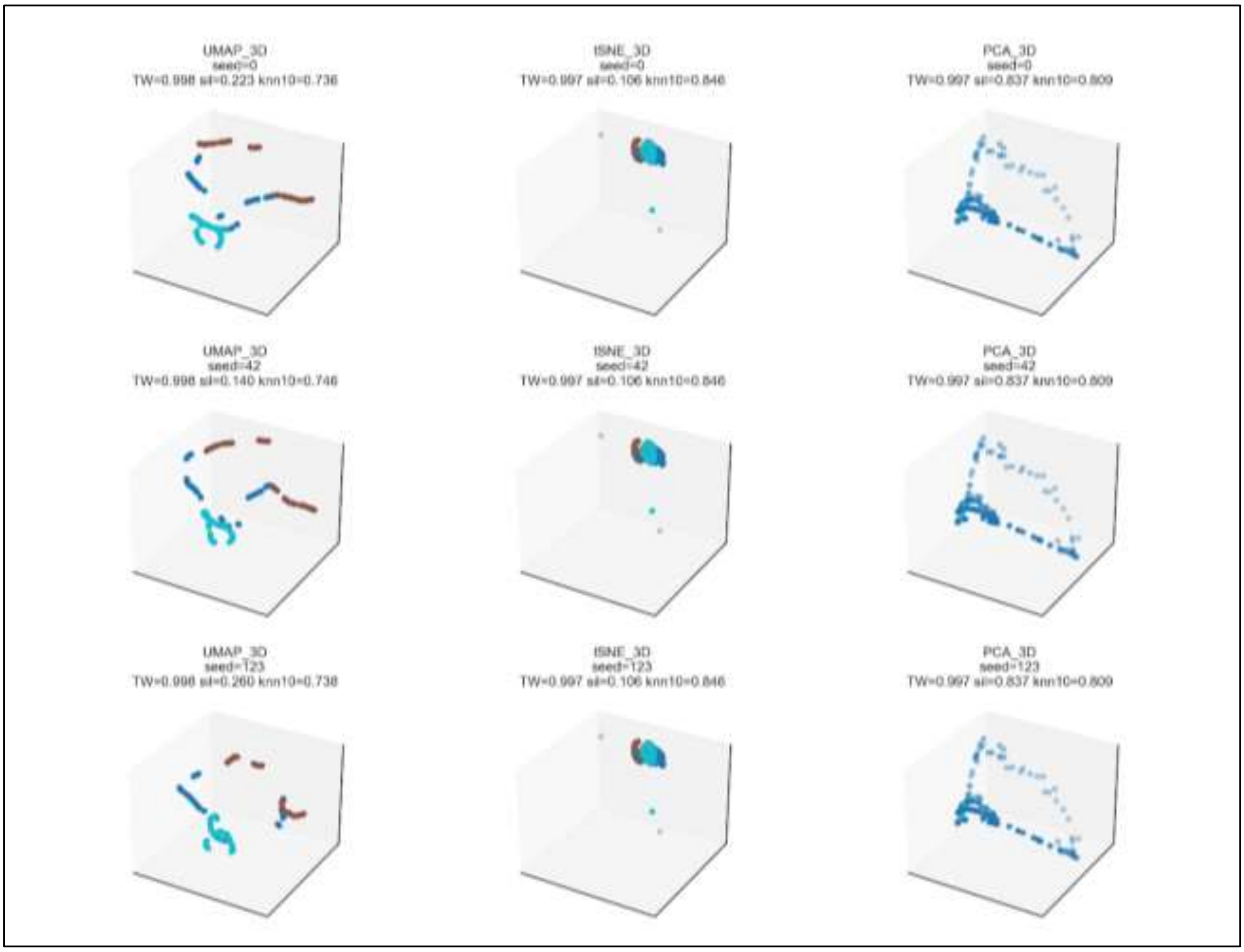

Figure 2 Stability Grid, 3D embeddings across seeds (rows) and methods (columns)

Figure 2 shows 3-D embeddings across three random seeds to evaluate stability. Trustworthiness is uniformly high across all methods (≈ 0.997 – 0.998), indicating strong local neighbourhood preservation after pre-PCA. However, cluster separation differs, PCA in 3-D produced the highest silhouette (≈ 0.84), showing clear volumetric separation of the KMeans clusters, whereas UMAP 3D produced modest silhouette values (≈ 0.14 – 0.26) and t-SNE 3D produced low silhouette (≈ 0.11) despite high k-NN overlap (≈ 0.85). This pattern indicates t-SNE maintains small neighbourhood fidelity but arranges neighbourhoods so that original cluster labels are interleaved rather than forming single cohesive regions in 3-D. PCA 3D, in contrast, captures global axes that separate the clusters. Results were largely stable across seeds. All three methods preserve local neighbourhoods well, but they behave very differently for cluster separation in 3D. Backed by high silhouette, PCA 3D shows the strongest cluster separation, UMAP 3D gives good local preservation with modest separation and t-SNE 3D preserves neighbours very well yet shows poor silhouette. This means that t-SNE's 3D layout clusters neighbours together but not in a way that separates the original KMeans labels into distinct regions.

Conclusion

PCA, t-SNE, and UMAP each offer

distinct trade-offs. PCA is fast and interpretable but linear. t-SNE excels at revealing local clusters but is slower and distorts global structure, whereas UMAP is fast, scales well, and often preserves more global organization than t-SNE but is parameter-sensitive. Systematic comparison shows that no single embedding is best for every purpose, UMAP especially in 3-D offers the best balance for recovering local neighbourhood structure and producing interpretable cluster layouts, t-SNE in 2D gives comparably crisp visual clusters and excellent local fidelity but requires careful hyperparameter tuning and is less convenient for out-of-sample mapping, while PCA particularly in 3D preserves global pairwise relationships and variance. This makes it the most interpretable linear baseline but drastically fails to untangle highly nonlinear manifolds.

Quantitatively, nonlinear methods achieved the highest trustworthiness and k-NN overlap whereas PCA scored highest on global rank preservation. Qualitatively, UMAP/t-SNE revealed the manifold and cluster structure that PCA collapsed. Future work should apply these diagnostics to real-world datasets and probe downstream impacts (e.g., clustering/classification performance). Prefer PCA for quick, interpretable linear structure and as a denoising stage before nonlinear embeddings to enhance speed and stability. Use t-SNE to uncover fine-grained local clusters in small to medium datasets while accepting slower performance and weaker global fidelity and choose UMAP for larger datasets that need both local detail and a reasonable global layout with better computational efficiency than t-SNE.

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Special Pest Management in Andhra Pradesh

Abstract

Pest incidence in major crops of Andhra Pradesh poses significant challenges to agricultural productivity. Traditional chemical control methods, though effective in the short term, have resulted in resistance, environmental hazards, and rising input costs. Special Pest Management (SPM) emphasizes an integrated approach combining biological, cultural, and technological practices with community-based pest surveillance. This paper highlights the major pests affecting key crops in Andhra Pradesh, outlines strategies adopted under special pest management programs, and discusses their effectiveness in ensuring sustainable crop production.

Keywords: Special Pest Management, Integrated Pest Management, Andhra Pradesh, Paddy, Cotton, Pest Surveillance, Eco-friendly Practices

Introduction

Andhra Pradesh is one of the leading agricultural states in India, with crops such as paddy, cotton, maize, sugarcane, chillies, and groundnut forming the backbone of its economy. Pests like brown planthopper (paddy), pink bollworm (cotton), and thrips (chillies) have historically caused severe yield losses. Conventional pesticide use has led to ecological imbalance and health hazards. To address these issues, the state has promoted Special Pest Management (SPM) strategies, with a focus on sustainable practices and farmer participation.

Major Crop Pests in Andhra Pradesh

- Paddy: Brown planthopper (Nilaparvata lugens), yellow stem borer (Scirpophaga incertulas), gall midge (Orseolia oryzae).- Cotton: Pink bollworm (Pectinophora gossypiella), whitefly (Bemisia tabaci), jassids (Amrasca devastans).- Chillies: Thrips (Scirtothrips dorsalis), mites (Polyphagotarsonemus latus).- Groundnut: Leaf miner (Aproaerema modicella), Spodoptera (Spodoptera litura).- Sugarcane: Early shoot borer (Chilo infuscatellus), pyrilla (Pyrilla perpusilla).

Special Pest Management Strategies

1. Integrated Pest Management (IPM)

- Use of biocontrol agents like Trichogramma chilonis.- Neem-based formulations for sucking pests.- Pheromone and light traps for insect monitoring.

2. Pest Surveillance and Forecasting

- Village Level Pest Surveillance (VLPS) systems monitor pest outbreaks.- Digital platforms and mobile-based advisories provide real-time alerts.

3. Community-Based Practices

- Farmer Field Schools (FFS) for capacity building.- Bird perches in fields to enhance predation.- Trap crops (e.g., marigold in cotton fields).

4. Emergency Pest Campaigns

- State-led drives during sudden outbreaks (e.g., BPH in paddy, pink bollworm in cotton).- Subsidized supply of pheromone traps, bio-pesticides, and drone spraying.

Case Studies

- Brown Planthopper in Paddy: Community surveillance in East Godavari prevented large-scale outbreaks by issuing early warnings.- Pink Bollworm in Cotton: Adoption of pheromone traps and coordinated sprays reduced incidence significantly in Guntur and Prakasam districts.

Challenges

- Dependence on chemical pesticides continues in certain regions.- Climate change alters pest population dynamics.- Greater farmer training is required for widespread adoption of eco-friendly practices.

Conclusion

Special Pest Management in Andhra Pradesh represents a comprehensive framework integrating eco-friendly techniques, community participation, and technological interventions. These practices have demonstrated success in mitigating pest damage while promoting sustainable agriculture. Strengthening surveillance networks and enhancing farmer awareness remain critical for long-term pest resilience.

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Micro Plastics in Soil: Hidden Pollutants and the Future of Remediation

Introduction

Tiny pieces of plastic — microplastics (MPs, <5 mm) — are widespread in soils from farms to city parks. They arrive with plastic mulches, composts and biosolids, tire wear, atmospheric fallout and runoff. Evidence from field surveys and lab experiments shows MPs change soil structure, modify microbial communities, interact with heavy metals and organic pollutants, and can reduce plant performance. A large 2025 meta-analysis even links MP exposure to a 7–12% reduction in photosynthesis across ecosystems. Measurement methods remain inconsistent, and remediation at scale is still experimental. The most pragmatic path today is upstream prevention (source reduction, better waste handling) paired with targeted remediation of high-risk hotspots while we build standardized monitoring, field trials and cost–benefit evidence.

Why soil microplastics matter now ?

Two recent facts capture why MPs in soil demand urgent attention. First, soils have been shown to host substantial MP burdens where human activities supply them — from repeated biosolid (sewage sludge) spreading to intensive plasticulture. Multiple field surveys demonstrate elevated particle counts in agricultural and peri-urban soils compared with remote sites. For example, sewage sludge application has repeatedly been identified as a major conduit of fibers and fragments into farmland.

Second, large-scale evidence suggests ecological consequences that could scale to agronomic losses. A very recent meta-analysis synthesizing 3,286 datapoints concluded that "MP exposure leads to a global reduction in photosynthesis of 7.05 to 12.12%," a striking signal that links MP pollution to primary production declines across ecosystems. This study does not by itself prove crop-level yield losses everywhere, but it raises a plausible risk to food security that demands field validation.

Taken together, prevalence plus the emerging signal of biological impact mean soil MPs should be treated as a bona fide soil-quality stressor, alongside salinity, heavy metals and organic contaminants. Science commentators and policy fora have thus urged soil scientists to move from laboratory curiosities to realistic, field-based measurement and mitigation.

Where do soil microplastics come from : sources and pathways

MPs enter soils via multiple, sometimes overlapping, routes:

- **Intentional agronomic inputs**: Plastic mulches and greenhouse films fragment in situ; composts and biosolids applied as fertilizers introduce fibres and fragments (example: long-term sludge-amended fields showing stepwise increases in fibre counts after repeated applications).

- **Urban and transport sources**: Tire and road wear particles, street dust and litter deposit in roadside soils and peri-urban fields. Imagine a field next to a busy highway — its verge often contains very different particle spectra (high in black elastomeric particles from tires) than an inland field.

- **Atmospheric deposition**: Airborne microfibers from textile shedding and construction dust can rain out onto soils kilometers from urban centres; studies detect microfibers even in apparently pristine uplands.

- **Diffuse hydrological transport**: Runoff, flood deposition and irrigation with reclaimed wastewater move MPs laterally; flooding events can create hotspots in floodplains and lowlands.

- **Biotic vectors and soil engineering**: Earthworms, ants and soil arthropods ingest and excrete MPs, redistributing particles vertically and horizontally in the profile (an important route for sub-surface movement).

Hotspots are predictable: intensively plastic-mulched horticultural plots, long-term sludge-amended croplands, and land near waste processing facilities. Polymer spectra commonly mirror production and use patterns — polyethylene (PE), polypropylene (PP) and polystyrene (PS) dominate many studies.

Measuring MPs in soil: why method mattersnand how to avoid false conclusions

A central bottleneck for progress is analytical heterogeneity. Soil is a complex matrix (minerals, aggregates, organic matter) and protocols vary widely in sieving cut-offs, density separation media (NaCl, $ZnCl_2$, NaI), organic-matter digestion (enzymes, peroxide) and identification (visual sorting, μ-FTIR, μ-Raman, thermochemical methods such as Py-GC-MS). Each choice biases which particles you detect: heavy-density or weathered polymers may be lost, small particles (<20 μm) require high-resolution spectroscopy, and thermal methods report mass not particle counts. Recent method reviews strongly recommend complementary methods (spectroscopy + thermal mass), routine procedural blanks, spike–recovery tests and dual reporting (particles kg^{-1} + mg kg^{-1}) to improve comparability.

Practical advice for researchers designing field studies:

- Always report sample dry mass, sieving/filtration thresholds and density media.

- Include field and laboratory blanks to track contamination (clothing fibres are a notorious lab artefact).

- Use particle-level spectroscopy (μ-FTIR/μ-Raman) for morphology and polymer ID where possible, and pair with thermochemical methods for polymer mass.

- Report both particle counts and mass to enable ecological and mass-balance interpretations.

Fate in the soil: retention, movement and weathering

MPs are not static. Most initially accumulate in topsoils, but movement occurs at ecological timescales:

- **Vertical migration** is controlled by particle size/shape (small, spherical particles move fastest), soil structure (macropores and preferential flow paths), tillage and bioturbation. Field column studies show mixed outcomes: some sites retain MPs near the surface for years, others exhibit measurable downward redistribution driven by earthworms or heavy rains.
- **Weathering and fragmentation**: UV, freeze–thaw and abrasion break macroplastics into secondary MPs and change surface chemistry. Weathered surfaces become rough, sorb more hydrophobic contaminants and host distinct microbial biofilms (the "plastisphere"). Weathering also promotes additive leaching (plasticizers, flame retardants) that complicate toxicological assessments.

Example: a polyethylene mulch film left on the soil surface for years fragments into a mix of films, fragments and fibers; paired earthworm activity can drag fragments into macropores, making remediation by surface raking ineffective.

Biological and Physicochemical Impacts — Experimental Insights

Controlled studies show varied effects of microplastics (MPs), influenced by concentration, type, and ecological endpoint:

- **Soil Structure & Water Dynamics:** MPs can disrupt aggregate stability and infiltration; fibrous types may enhance water retention via microfiber networks. Changes in porosity and bulk density affect hydraulic conductivity and plant-available water, with outcomes dependent on system context.
- **Microbial Communities & Plastisphere:** MPs rapidly form biofilms distinct from native soil microbiota. Shifts in carbon/nitrogen enzyme profiles and reduced microbial diversity are reported, though landscape-scale functional impacts remain uncertain.
- **Plant Physiology & Photosynthesis:** MPs reduce germination, root growth, and biomass in sensitive species. A PNAS meta-analysis (3,286 datapoints) found a 7–12% decline in photosynthesis across ecosystems — a concerning trend with crop relevance.
- **Soil Fauna:** Earthworms and collembolans ingest MPs, showing effects from negligible to sub lethal stress. Their activity redistributes MPs via burrowing and casting.

Many studies use high MP doses, single polymers, or short durations. Field-relevant, chronic, mixed-polymer scenarios need priority attention.

MPs and Co-Contaminants — A Multi-Stressor Challenge

MPs act as vectors for hydrophobic organics, metals, and antibiotics, often concentrating pollutants and antibiotic-resistance genes. Combined exposures (e.g., MPs + Cd) increase plant uptake and toxicity.

- Example: Sludge-amended soils may form hotspots of Cd, antibiotics, and MPs — amplifying ARG enrichment and ecological risks.

Remediation — Strategies and Limitations

- Soil remediation is complex due to MPs' particulate nature and integration with organic matter. Approaches include:
- Prevention & Management
- Limit inputs: redesign mulches, regulate sludge, manage textile waste.
- Policy tools (e.g., compost standards, producer responsibility) offer scalable impact.
- Physical/Ex Situ Removal
- Excavation, sieving, and soil washing work locally but disturb structure and generate secondary waste.
- Magnetic/electrostatic methods show lab promise but lack field viability.
- Bioremediation
- Enzymes, fungi, and bacteria can degrade MPs in lab settings.
- Field-scale mineralization remains rare; safety and efficacy must be proven.
- Phytoremediation & Amendments
- Plants and biochar may immobilize MPs/co-contaminants, but sequestration ≠ removal.
- Long-term stability and ecological effects require evaluation.
- Hybrid, Risk-Based Approaches
- Target high-load hotspots (e.g., sludge sites) with combined excavation, washing, and thermal treatment.
- Integrate source control and weigh soil-health trade-offs.

Key research and policy priorities (a practical checklist)

For soil scientists and funding agencies I propose these immediate priorities:

1. **Global method harmonization** — inter-laboratory ring tests, agreed size classes and dual reporting (counts + mass).

2. **Realistic, long-term field trials** — mixed polymers, environmental concentrations, multi-year monitoring including crop uptake measurements.
3. **Mechanistic ecotoxicology** — separate physical (pore clogging) from chemical (additive leaching, sorbed co-contaminants) mechanisms using integrated soil-plant-microbe experiments.
4. **Hotspot remediation trials** — demonstrate scalable solutions for sludge-legacy fields, with soil-health indicators and socioeconomic costing.
5. **Policy-science linkages** — produce evidence packages on what management changes (e.g., sludge treatment standards, mulch design) achieve in terms of load reduction. Scientists should engage directly with regulator and farmer networks.

Final thoughts — what should practitioners and readers take away?

Microplastics in soil are now a tractable, interdisciplinary problem — but not a problem with a single technological fix. The hierarchy is simple and familiar: **prevent** > **monitor** > **prioritize** > **remediate**. Prevention through product redesign, improved waste and sludge management, and circular-economy solutions will deliver the largest benefits at lowest cost. Where legacy hotspots exist, we need risk-based, site-specific remediation trials that weigh soil-function preservation against contaminant removal.

For researchers: design experiments that reflect the messy reality — multiple polymers, low doses, ecological complexity, and time. For policymakers: invest in standard measurement infrastructure and in upstream interventions (sludge quality, mulch standards). And for farmers and land managers: adopt best practices that minimize plastic escape — careful removal of degraded mulch, improved compost screening and judicious use of recycled biosolids.

Microplastics have moved from curiosity to credible environmental stressor. The science is accelerating, but so must the translation into practical monitoring and sensible policies. The soil beneath our feet deserves no less.

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Biomass Briquetting: The Process of Converting Waste into Energy

Abstract

This paper provides a concise overview of converting agricultural and forestry waste into high-density fuel briquettes. It outlines the step-by-step process, from collection to packaging, and explores briquette applications in various sectors. The document highlights how this technology offers a sustainable, cost-effective, and environmentally friendly solution for waste management and energy production, particularly in agricultural regions like southern India, where it can replace coal

Introduction

In Recent years, the need for sustainable and alternative energy sources has become more critical than ever. The extensive use of fossil fuels and the practice of burning agricultural waste for disposal contribute significantly to environmental degradation and climate change. Biomass briquetting emerges as a powerful and practical solution to these challenges. By transforming low-density biomass waste into a compact, energy-rich fuel, briquetting not only addresses the issue of waste management but also provides a cleaner, more efficient energy source. This document will guide you through the meticulous process of making briquettes and detail their wide-ranging applications, showcasing their potential to replace coal and foster a greener economy.

Process of Making Briquettes

Briquettes are a clean, high-density fuel created from agricultural and forestry waste. The process of making them is a simple but effective way to convert low-density, bulky biomass into a compact, energy-rich fuel source. This guide outlines the key steps involved, from collecting raw materials to creating the final product.

1. Collection and Preparation of Raw Material

The process begins with the collection of various types of biomass waste. In southern India, this often includes residues from groundnut shells, sugarcane bagasse, rice husks, coffee husks, and sawdust. This raw biomass is collected from farms, sawmills, or other sources where agricultural and forestry waste is abundant.

2. Crushing and Grinding

After drying, the biomass is fed into a crusher or a pulverizer. This step is crucial for achieving a uniform particle size, which is necessary for effective compaction. The grinding machine breaks down the raw material into a fine, consistent powder. This uniformity is a key factor in producing briquettes with consistent density, strength, and calorific value.

3. Briquetting (Compression)

This is the core of the briquetting process. The ground biomass is fed into a briquetting press, which applies high pressure and, in some cases, high temperature. The two most common types of presses are the piston press and the screw press. The high pressure from the press compresses the biomass, causing the lignin—a natural polymer within the plant fibers—to soften and act as a natural binder. No external chemical binders are typically needed. The raw material is forced through a die, where it is compacted into its final shape, most commonly cylindrical or hexagonal.

4. Cooling and Hardening

As the hot, newly formed briquette exits the press, it is transported through a cooling line. This allows the briquette to cool down and solidify. As it cools, the natural lignin binder sets, giving the briquette its final hardness and durability. The cooling process also helps the briquettes retain their shape, preventing them from breaking apart during storage and transportation.

5. Packaging and Storage

The finished briquettes are then ready for packaging and storage. They are typically stored in a dry, covered area to prevent them from absorbing moisture, which would reduce their efficiency as a fuel. For commercial use, they can be packaged in bags or stacked neatly for easy transport to industrial boilers, power plants, or domestic users. The compact nature of briquettes makes this final step highly efficient and cost-effective

Applications and Use Cases

- **Industrial:** Many industries, including textile, food processing, chemical, and brick manufacturing, use briquettes in their boilers and furnaces. They provide a reliable source of heat and steam for various processes.
- **Domestic:** In rural areas, briquettes can be used as a cooking and heating fuel, offering a cleaner and more efficient alternative to firewood.
- **Power Generation:** Thermal power plants are increasingly using briquettes for "co-firing," where they are burned alongside coal to reduce the plant's carbon footprint

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Creative Ways to Reuse Old Pots and Planters

Introduction

As sustainability becomes more central to modern living, gardeners and homeowners alike are looking for creative, eco-friendly ways to reduce waste. One of the simplest and most effective methods? Repurposing old pots and planters. Whether they're cracked, faded, or simply no longer in use, these once-loved garden containers can find new life in surprisingly inventive ways.

Instead of tossing them in the trash, old pots and planters—terracotta, ceramic, plastic, metal, or wood—can be transformed into charming features for your garden, home décor, or even DIY crafts. This not only cuts down on landfill waste but also adds personality, rustic charm, and uniqueness to your space.

In this article, we'll explore creative, practical, and beautiful ways to reuse old pots and planters, turning would-be junk into functional treasures for both your garden and beyond.

1. Turn Old Pots into Vertical Gardens

Why Vertical Gardening?

Vertical gardens are a perfect solution for small spaces like balconies, patios, or urban gardens. Repurposing old pots for a vertical setup allows you to maximize your growing space and create a living wall filled with herbs, flowers, or succulents.

How to Do It:

- Stacking Method: Use three or more pots of descending sizes. Place the largest pot on the bottom, fill it with soil, and insert a dowel or metal rod in the center. Slide the next smaller pot down the rod, tilting it slightly for a cascading effect. Repeat for the next pot(s).
- Wall Hanging Planters: Drill holes into lightweight plastic pots and mount them to a wooden pallet or fence. Use as a vertical herb garden or floral display.

Best Plants to Use:

- Herbs: basil, thyme, mint
- Trailing flowers: petunias, lobelia, nasturtiums
- Succulents and cacti

Tip: Ensure adequate drainage in each container to avoid root rot

2. Create Unique Garden Art and Sculptures

Why Use Pots for Art?

Old pots—especially mismatched or chipped ones—can be transformed into whimsical and artistic features. Whether you're building a sculpture, garden gnome, or quirky figure, this adds character and playfulness to outdoor spaces.

Ideas to Try:

- Pot People: Stack different-sized pots to create human-like figures. Use rope to attach small pots for arms and legs. Paint on faces and dress with old scarves or hats.
- Totem Towers: Stack pots upside-down in interesting patterns, alternating colors and sizes for visual interest.
- Mosaic Planters: Break old pots and use the shards to create mosaic patterns on intact containers or stepping stones.

Materials Needed:

- Paint (outdoor-safe)
- Adhesive/sealant
- Pot shards or tiles
- Strong glue or concrete for stacking

Pro Tip: Spray-seal painted pots for longer life outdoors.\

3. Use Old Planters as Indoor Storage or Organizers

Functional and Stylish

Pots aren't just for plants—they can become attractive storage solutions inside your home. From rustic farmhouse aesthetics to minimalist modern designs, pots can fit a variety of décor themes.

Creative Storage Uses:

- Office Supplies: Store pens, rulers, clips, or small tools.
- Craft Station: Organize brushes, buttons, thread, or yarn.
- Bathroom Storage: Hold rolled towels, toiletries, or extra soaps.
- Kitchen Utensils: Use medium pots for wooden spoons, spatulas, or herb jars.

Design Tips:

- Paint or stencil to match your interior décor
- Wrap with jute rope or burlap for rustic charm

- Add labels or chalkboard paint for personalization

Idea: Stack small pots on a lazy Susan for a rotating craft or spice station.

4. Make Bird Baths and Feeders

Bring Wildlife to Your Garden

Attracting birds is both beneficial for pest control and adds life and sound to your garden. Old pots and saucers can be repurposed into bird baths or feeders with little effort.

DIY Bird Bath:

- Use a large clay pot turned upside-down as a pedestal.
- Place a shallow bowl or saucer on top, secured with weather-resistant adhesive.
- Fill with clean water and place in a shaded, quiet part of the garden.

DIY Bird Feeder:

- Hang small pots upside-down using twine or chain.
- Attach a saucer below filled with birdseed.
- Optionally, paint the pot for a decorative touch.

Tips for Success:

- Clean regularly to prevent algae and disease
- Use non-toxic paint and sealants
- Keep out of reach of pets or predators

5.Build a Fairy Garden or Miniature Landscape

How to Create One:

- Use a broken pot and arrange the shards as “terraces” or levels inside the container.
- Fill each layer with soil and miniature plants like moss, thyme, or succulents.
- Add small figurines, pebbled paths, fairy houses, or tiny benches.

Popular Fairy Garden Accessories:

- Mini birdhouses
- Tiny lanterns
- Painted stones
- Dollhouse furniture

Creative Touch: Add battery-powered fairy lights for evening charm.

6. Repurpose as Candle Holders or Lanterns

Cozy Ambience with Upcycled Style

Old pots, especially small or medium-sized terracotta ones, make great candle holders or rustic lanterns for patios and garden tables.

Candle Holder Ideas:

- Place pillar candles inside pots filled with sand or pebbles for stability.
- Paint or stencil pots for decorative flair.
- For a festive look, tie a ribbon or string of beads around the rim.

Lantern Conversion:

- Cut patterns or holes in lightweight plastic or metal planters.
- Insert tea lights or LED candles inside.
- Hang using chain or wire, or place on tables or steps.

Safety Note: Always supervise open flames and use flame-safe containers.

7. Convert Into Compost Bins or Worm Towers

Support Sustainable Gardening

Old, large pots can be turned into mini compost bins or worm towers for enriching your garden soil naturally.

A Garden Within a Pot

Cracked or chipped pots are perfect candidates for fairy gardens—miniature landscapes that spark creativity and storytelling.

Mini Compost Bin:

- Use a large plastic or ceramic pot with drainage holes.
- Fill with alternating green (vegetable scraps, coffee grounds) and brown (leaves, paper) materials.
- Stir occasionally and keep it moist but not wet.

Worm Tower:

- Bury a pot halfway into a garden bed.
- Add kitchen scraps and red wigglers (composting worms).
- Cover with a lid or another pot to keep pests out.
- Worms will naturally fertilize the surrounding soil.

Benefits:

- Reduces kitchen waste
- Improves soil fertility
- Great for small gardens or raised beds

8. Use as Raised Beds or Grow Towers for Small Plants

Gardening Made Accessible

Even if you're short on space or mobility, old pots can be stacked or grouped to create elevated raised beds or grow towers for herbs, strawberries, or lettuce.

How To:

- Stack several pots with holes drilled in the sides for planting pockets.
- Fill with soil and plant small edibles like strawberries or herbs.
- Alternatively, group several wide, shallow pots together to form a mini raised bed.

Best Crops for Pot Towers:

- Leafy greens (spinach, lettuce)
- Herbs (oregano, chives)
- Strawberries
- Radishes

Conclusion

Giving old pots and planters a second life is more than a practical solution—it's a creative journey. By transforming tired or broken containers into vertical gardens, bird baths, candle holders, storage solutions, or miniature landscapes, you're not only reducing waste but also injecting personality and charm into your space.

With just a bit of imagination and minimal tools, your once-forgotten pots can become functional, decorative, and deeply satisfying elements in your home or garden. Whether you're an eco-conscious gardener, a crafty DIYer, or simply someone with a few extra containers lying around, there's always a way to rethink, repurpose, and revive.

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Phytonanoparticles as Catalysts for Next-Generation Smart Technologies

Introduction

Nanotechnology has emerged as a prominent field in science, with applications in medicine, agriculture, and environmental protection. Traditional nanoparticle synthesis through chemical and physical methods enables precise control but incurs high costs: they are energy-intensive, use toxic chemicals, generate hazardous waste, and raise safety concerns. These limitations hinder large-scale application in healthcare and agriculture. Researchers have adopted green synthesis methods using plant extracts to produce nanoparticles more safely and sustainably. These phytonanoparticles leverage nanotechnology while maintaining ecological sustainability, exhibiting biocompatible and non-toxic properties suitable for various applications. In agriculture, phytonanoparticles are crucial for developing smart technologies for precision farming. By integrating with GPS, IoT sensors, and data systems, these nanoparticles can become intelligent fertilizers and pesticides that release ingredients when crops need them. They also function as nanosensors for monitoring soil health and crop stress, helping farmers optimize resource management. These innovations address challenges from excessive agrochemical use, including soil degradation and pesticide resistance.

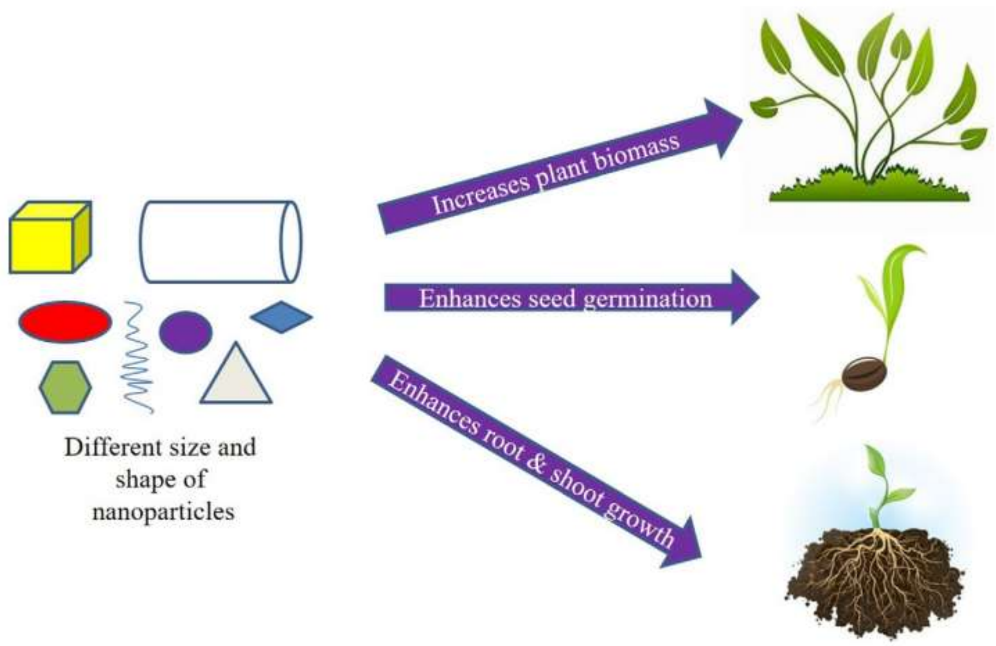

Figure 1. Impact of nanoparticles on plant growth

While scaling production and addressing regulatory issues remain concerns, phytonanotechnology integration with smart agriculture could redefine farming's future. Phytonanoparticles are nanoscale materials (1-100 nm) synthesized using plant extracts from leaves, roots, stems, fruits, and seeds, using plant-derived biomolecules as reducing and stabilizing agents.

Nanoparticle Synthesizing Methods

Several methods that use plant resources to create ecologically benign nanoparticles are known as phytonanoparticle synthesis. Table 1 provides a thorough summary of the many techniques used to create phytonanoparticles.

Types of Method	Overview	Process	Examples
Plant Mediated Biosynthesis	With this technique, whole plants or plant tissues are used to create nanoparticles.	When plant parts are submerged in metal ion solutions, the phytochemicals in the plants stabilise the nanoparticles and lower the metal ions.	Copper nanoparticle synthesis utilising basil leaf extract or iron oxide nanoparticle synthesis using aloe vera leaf extract
Green Chemistry Methods	Techniques that apply the concepts of green chemistry to reduce the usage of hazardous materials and improve environmental sustainability	This entails employing natural reducing agents and stabilisers made from plants, as well as optimising reaction conditions and non-toxic solvents.	Biosynthesis of silver nanoparticles utilising environmentally benign solvents and plant extracts, or synthesis of selenium nanoparticles using plant-derived polysaccharides as reducing agents.
Direct Plant Extract Method	This technique uses plant extracts with bioactive chemicals directly to stabilise nanoparticles and lower metal ions.	Water, ethanol, and other solvents are used to remove plant material (leaves, roots, and stems), which is then combined with metal salt solutions. Metal ions are reduced by the extract's phytochemicals to create nanoparticles.	Gold nanoparticles made with green tea extract or silver nanoparticles made with neem leaf extract
Bioreactor-Assisted Synthesis	Phytonanoparticle synthesis is controlled and scaled up using bioreactors.	In bioreactors, where regulated parameters (temperature, pH) maximise the production and yield of nanoparticles, plant extracts or cells are cultivated.	Production of silver nanoparticles utilising plant cell suspension cultures or gold nanoparticles in plant cell culture systems
Microbial-Plant Synergistic Methods	enhances the creation of nanoparticles by combining microbial systems with plant extracts.	To help reduce and stabilise nanoparticles, plant extracts are combined with microorganisms (such as	Zinc oxide nanoparticle synthesis employing plant extracts with bacteria or fungi present

		bacteria or fungi).	
Sustainable Scale-Up Techniques	emphasises expanding the synthesis process while preserving environmental viability.	creates systems and procedures to use sustainable methods to increase the production of phytonanoparticles from the lab to the industrial scale.	Scaled-up synthesis of gold nanoparticles utilising optimised plant extract techniques or large-scale manufacturing of silver nanoparticles using plant extracts in industrial reactors

Characterization methods and important physical characteristics

Phytonanoparticles require characterization through analytical techniques to determine their properties and applications. UV-visible spectroscopy confirms nanoparticle synthesis using surface plasmon resonance peaks to assess size. Transmission Electron Microscopy (TEM) provides high-resolution imaging of shape and size distribution. Dynamic Light Scattering (DLS) measures hydrodynamic size and zeta potential as stability indicators, while Scanning Electron Microscopy (SEM) reveals surface topography and composition. Fourier Transform Infrared Spectroscopy (FTIR) identifies surface biomolecules and functional groups, whereas X-ray diffraction (XRD) determines crystalline structure and phase composition. Thermogravimetric Analysis (TGA) assesses organic coating and thermal stability, while Energy Dispersive X-ray Spectroscopy (EDX) analyzes elemental composition. These techniques elucidate key physicochemical characteristics of phytonanoparticles, including size distribution, shape, morphology, surface charge, zeta potential, crystallinity, surface area, porosity, optical properties, stability in media, and surface coating composition. This characterization is essential for understanding phytonanoparticle behavior and applications in biological and environmental contexts.

Objectives of Ecofriendly Methods Use in Phyto-Nanoparticle Synthesis

1. Hazardous chemicals and processes that might damage the environment are frequently used in traditional ways of synthesizing nanoparticles. The goals of eco-friendly practices are to reduce environmental contamination and minimize the use of harmful substances.
2. Using natural, nontoxic materials and procedures is the goal to adhere to the principles of green chemistry. This entails producing nanoparticles using biological agents or plant extracts, thereby avoiding hazardous chemicals and minimizing waste.
3. In the long term, eco-friendly practices might frequently be more economical. Utilising easily accessible and reasonably priced resources, plant-based or biological approaches may lower the total cost of producing nanoparticles.
4. By using fewer dangerous chemicals, workers are safer, and the health risks of being around harmful substances are reduced. Eco-friendly practices rely on natural processes to protect human health and well-being.
5. Numerous environmentally friendly techniques are scalable and suitable for large-scale manufacturing. By using locally available plants or biological materials, they can also be more accessible in areas with limited resources.
6. Plant-based synthesis occasionally gives nanoparticles special characteristics. For example, the presence of natural chemicals in the plant extracts may promote stability, bioactivity, or interactions in phytonanoparticles.
7. Sustainable practices are preferred by the public and government when eco-friendly solutions are used. Green techniques can

enhance the marketability and acceptance of nanoparticles in various applications.

8. Comparing these techniques to traditional procedures, they usually result in less chemical waste. Byproducts are often less harmful, making the synthesis process cleaner and more effective.

Smart Applications in Agriculture

Nanofertilizers : Leaching, runoff, microbial and photolytic destruction, hydrolysis, and evaporation are some of the major losses that conventional fertilisers that are sprayed or spread frequently experience. In addition to decreasing fertiliser efficacy, these inefficiencies lead to environmental contamination, soil nutrient imbalance, damage to soil microflora, fauna, and bird habitats, and increase resistance to pests and diseases. On the other hand, controlled and targeted nutrition delivery is made possible by nanofertilizers, which are nutrient carriers at the nanoscale, lowering waste and environmental hazards. In order to improve fertiliser efficacy, nutrient uptake, and cost-effectiveness while preserving ecological balance, their encapsulated architectures enable slow, rapid, moisture-, pH-, or stimulus-responsive release (Figure 1).

Nanoparticles such carbon nanotubes, silver, zinc oxide, cerium oxide, silicon, titanium dioxide, copper, gold, palladium, and magnesium oxide have been found to improve photosynthesis, seed germination, chlorophyll content, root and shoot growth, and crop output. By increasing proline accumulation, water-use efficiency, nitrate reduction, antioxidant activity, and photochemical efficiency, they also increase stress tolerance. The biochemical and physiological enhancements in crops such as rice, maize, tomato, tea, and legumes are further supported by biosynthesised and phytomediated nanoparticles derived from fungi and plant extracts. Overall, by increasing yield, cutting expenses, and lessening environmental effects, nanofertilizers show great promise to transform agricultural nutrient delivery systems.

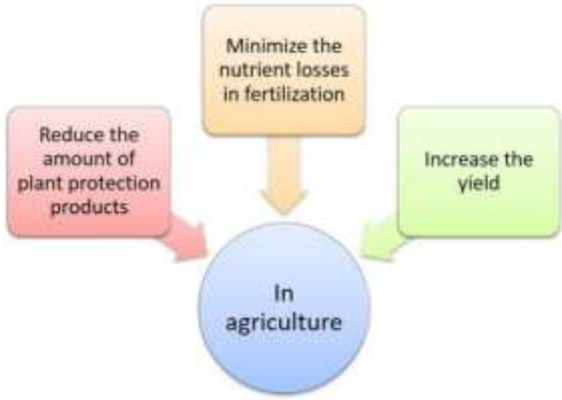

Figure 2. Nanofertilizer applications in agriculture

Nanopesticides: Insects inhabit diverse habitats and feed on various plants. They contaminate crops and storage items, causing significant losses. Only insects inflicting 5% damage are regarded as pests. Insect pests cause 14% of damage. Conventional techniques included integrated pest management, crop rotation, and adjusted planting dates. Farmers began using chemical-based insecticides after the green revolution. When dichloro diphenyl trichloroacetic acid (DDT) was developed, farmers were amazed by its effectiveness against most bug species. More pesticide varieties were created, with toxic heavy metals as their basis. Insects became resistant due to genetic changes from increased pesticide usage. Farmers face pressure to increase agricultural production costs. Environmental studies focused on developing eco-friendly agents due to restrictions and adverse human effects. Validamycin-loaded porous hollow silica nanoparticles (PHSNs) provide regulated pesticide delivery. Insects absorb nanosilica through cuticular lipids, causing physical death. PHSNs are promising agricultural carriers for controlled pesticide delivery that plants need for immediate or prolonged release.

Biosynthesised silver nanoparticles (Ag NPs) from Cassia roxburghii leaf extract managed fungal plant diseases. Au and Ag NPs from T. atroviride were effective against Phomopsis theae. In soil, they reduced tea plant cankers and increased leaf production. Ag NPs from S. rebaudiana showed antifungal properties against Aspergillus niger. Fe

NPs from Azadirachta indica extract inhibit apple phytopathogens. Fusarium oxysporum f. sp. lycopersici's cell wall polymer (chitosan) was cross-linked using sodium tripolyphosphate synthesised nanoparticles (CWP-NPs). These biosynthesised NPs improved yield, reduced wilt disease, and delayed tomato plant symptoms.

Nanosensors for soil and crop health: Applications for nanosensors in agriculture are promising. Nanosensors give real-time data on the presence and location of pesticides and diseases. Nanobiosensors also enable the real-time monitoring of crops by forecasting field and environmental variables. By detecting phytopathogens, weeds, plant diseases, ambient pollution, and soil nutrition conditions and concentrations, nanobiosensors combined with bioreceptors can increase productivity. Using silica nanoparticles, fluorescent nanoprobes linked with goat antirabbit secondary antibodies were created to identify the plant pathogen Xanthomonas axonopdis, which damages solanaceous plants. Plant pathogen detection has been accomplished using Au NPs, silicon NPs, CNTs, and nanowires.

Shaping Tomorrow: The Promise and the Challenges

Phytonanoparticle green synthesis represents a notable advancement in safety and sustainability within the domain of nanotechnology. This green synthesis employs biotechnological approaches that utilize plants to replace toxic solvents and precursors in the production of nanomedicines, which are both effective and pose a reduced environmental risk. The scientific community and regulatory bodies must acknowledge the significant challenges that hinder the comprehensive application of phytonanoparticles by industry, governments, and regulators. The primary challenge is scalability. A crucial step forward is to ensure the rapid and reproducible production of nanosized particles of consistent quality in large quantities. A fundamental question confronting the scientific community is how to achieve consistency in the production of phytonanoparticles from various plant species and using different methodologies. Additionally, there is an urgent need for more rigorous testing of the safety and toxicity of phytonanoparticles to determine the acceptability of new materials for human and environmental applications. Furthermore, effective regulations and guidelines must be established and implemented to foster confidence in the production and application of phytonanoparticles across various industries, such as medicine, agriculture, and environmental remediation, thereby restoring confidence in the potential to sustain greener nanotechnologies in the marketplace. Addressing these challenges will enable phytonanoparticles to play a vital role in health, agriculture, and other environmentally sustainable applications, contributing to the achievement of sustainability.

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Plant-Parasitic Nematodes in Tuberose: Challenges and Management Options

Introduction

The floriculture sector has emerged as a sunrise industry in India, driven by the growing domestic and international demand for cut flower crops such as rose, chrysanthemum, carnation, gladiolus, tulip, lily, and others. While high-value crops like gerbera and carnation are mainly cultivated under protected polyhouse conditions, several ornamentals including rose, chrysanthemum, marigold, aster, tuberose, and jasmine are predominantly grown in open fields. Major floriculture-producing states include Maharashtra, Karnataka, Andhra Pradesh, Haryana, Tamil Nadu, Rajasthan, and West Bengal.

Among the various constraints affecting ornamental crops, plant-parasitic nematodes constitute a serious yet often underestimated problem. These microscopic soil-inhabiting pests parasitize roots, stems, bulbs, and underground plant parts, leading to gradual but significant production losses. Their insidious mode of life cycle, concealed soil-borne nature, and non-specific or overlapping feeding symptoms often obscure their true impact in crop health assessments. In addition, nematodes interact synergistically with soil-borne fungi and bacteria, thereby aggravating disease complexes and predisposing plants to biotic as well as abiotic stresses.

The extent of yield loss due to nematodes is not solely dependent on their population density but is also governed by several biophysical and ecological factors including host plant susceptibility, soil temperature, texture, soil micro biome composition, and prevailing environmental conditions. Once nematode populations exceed the threshold level, significant yield reductions and economic losses become evident.

Tuberose (*Polianthes tuberosa* L.), an important ornamental known for its graceful appearance and sweet fragrance, is one of the most commercially valued flower crops in the world. It commands high demand in the cut flower market and is also exploited for essential oil extraction due to its aromatic blossoms. Its flowers are widely utilized in artistic garlands, bouquets, religious offerings, floral arrangements, and perfumery. In India, major tuberose-growing regions include West Bengal, Karnataka, Tamil Nadu, and Maharashtra.

Area and Production:

For the last two years, tuberose (*Polianthes tuberosa* L.) has maintained a significant presence in India's floriculture production, with cultivation concentrated in major states such as West Bengal, Karnataka, Tamil Nadu, and Maharashtra.

The area under tuberose in India was approximately 14,000 to 15,000 hectares across recent years, with annual production of loose flowers totaling about 106,000 metric tonnes and cut flowers about 89 million stems in 2023. Final figures for 2024 remain comparable, with negligible changes in area and overall production according to state-wise reports and the National Horticulture Board.

Plant parasitic nematodes like *Aphelenchoides besseyi* (foliar nematode), *Meloidogyne* spp. (root knot nematode*)* *Pratylenchus* spp. (lesion nematode) are commonly associated with this crop and cause heavy serious damage (Picture 1, 2, 3)

1. Floral Malady disease of tuberose by *Aphelenchoides besseyi*:

The floral malady was first observed by Rhanghat areas of Nadia district of West Bengal.

This disease is mainly observed in West Bengal and Odisha. The pre adults and the adult stages of *A. besseyi* survive in the quiescent stage up to two years in dried leaves outside the bulbs. They do not survive in the soils. The maximum number of nematodes are present in outermost scaly leaves and neck region of the infested individual bulb, also more number of nematodes are recovered from the central bulbs. At 30 C one cycle is completed in about 10 to 12 days. The nematodes are spread to the fresh plants from the bulbs, dry plant parts and through irrigation water.

Symptoms:

- In this disease, a small discrete spots appear near midrib of tube rose leaves.
- These spots gradually enlarge along midrib and form elongated and black greasy spots which are about 5 to 15 cm long.
- The leaves bend, wilt and finally dry up.
- Flower stalks appears as rough and crinkled. They are then distorted and stunted. On petals and leaf bracts the rusty brown spots are developed and floral buds fail to bloom in severe cases.
- Over drying, the severely infected flower stalks becomes rotten and brittle. The number of flowers per stalk are reduced. This produces the small crinkled and distorted flowers which have a very poor market value which causes revenue loses to the farmers (picture 2.)

Management:

- To control floral malady of tube rose, the bulbs are soaked overnight in water or 5 % NSKE or they can be dipped in monocrotophos (36SL) at 0.05 % for 6 hours.
- The nematode infected plant parts should be destroyed.
- Under chemical treatment, after the bulbs sprouts, spray monocrotophos (36SL) 0.05% 3-4 times at two weeks interval. In second and third year, spray monocrotophos (36 SL) 0.05 % 3-4 times @ 15 days interval in the beginning of April.
- During peak flowering stage additional spraying with Neem Seed Kernel Extract (NSKE) 5% at 15 days interval should be done
- Infested plant parts should be collected and burnt immediately.
- The run-off or irrigation water from infested field should be restricted to enter the healthy, nematode free fields of tube rose.

2. Root knot disease by *Meloidogyne* spp.

The another disease in tube rose is caused by root knot nematode which is caused either by *M. incognita*. The yield is reduced by 10 percent. This is mainly prevalent in Karnataka, Western Uttar Pradesh, Odisha, West Bengal. The plants show the retarded growth as the leaves are dried off after yellowing and number of spikes are reduced. The galls appear on the roots. The nematodes interact with fungus *Fusarium oxysporium* f.sp. *dianthi* leading to most serious disease complex. Like *A. besseyi* root knot nematode also gets transmitted through infected planting material, agricultural implements and irrigation water. The life cycle is completed in 25-30 days during the months of summer. As root knot nematode is sedentary endoparasite, it feeds on the vascular tissues. Adults females are sac like and lay eggs in masses on root surface or inside the compound galls.

Symptoms:

A. Above ground field symptoms

a. Stunted growth, reduction of foliage and decline of plants progressively

b. Chlorosis of leaves

c. Leaf with angular leaf spots and necrosis and wilting of plants

d. Early senescence and poor yield

e. Reduction in number of spike with distorted foliage like crinkling, curling and twisting); flowers (floral malady)

B. Below ground symptoms

a. Root knot or root gall formation, swelling of root tip (picture 1)

Management strategies:

- As the management options, the use of healthy bulbs free from the galls are recommended.
- The bulbs should be cleaned and dipped for 4-6 hours in 0.05% carbosulfan (25 EC) solution or soil application of carbofuran (3G) at 2 g/plant. If the farmer goes for organic cultivation they can apply neem cake @ 1 ton per hectare.
- They can also go for VAM, pongamia or castor cake or in combination of *Purpureocillium lilacinum* can be used.
- If nematode disease complex appears the combination of bioagents like *Pochonia chlamydosporia* along with *Trichoderma harzianum* or *P. lilacinum* along with *T. harzianum* can be applied in soil enriched in FYM (1 kg/ton) was found to most effective and economic.

Picture 1. Tuberose roots infested with root knot nematode

Picture 2. Tuberose flowers infested with *Aphelenchoides besseyi*

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CRISPR technology: Rewriting agriculture

"Use of CRISPR technology in Agriculture"

Introduction

This approach, which is widely employed in agriculture to improve crop traits such as stress tolerance, disease resistance, and others, speeds up breeding by using precise tools is targeted CRISPR technology. This changes yield/quality that may be completed over a few generations. CRISPR makes many things possible from minor deletions in genome to single-base changes and promoter tuning. CRISPR–Cas technologies enable exact alterations in plant genomes that let targeted trait enhancement occur faster and really better than classic breeding or earlier used genome-editing techniques. It ranges from basics to carefully calibrated allele modifications that regulate expression or protein function for complex features, the toolkit now encompasses Cas9/Cas12, base editors, and prime editors. Delivery methods including nanoparticles systems, viral vectors, and DNA free RNPs are increasing edit access across species and, in certain cases, lowering off-targets and regulatory complexity.

Basics of this technology are Trait improvement, Creating strong pathogen and insect pest resistance and abiotic stress tolerance. Trait improvement can be defined as the changing of genes to enhance the yield components, grain quality, shelf life, and nutritional profiles of important crops like rice, wheat, maize, and horticultural species. Creating strong pathogen and insect pest resistance can be achieved by employing creative CRISPR-based plant protection strategies, such as multiplex modifications, CRISPRCas etc... Abiotic stress tolerance is increasing tolerance to drought, heat, salt, and nutrient deficits in order to sustain production in the face of today's climate change.

Currently followed editing methods are Prime and base editing, Transcriptional/epigenetic control, tiny and diverse CRISPR systems. Prime and base editing are done with fewer undesirable variations, exact nucleotide modifications that do not cause double-strand breaks allow for the optimization of agricultural alleles. Transcriptional/epigenetic control is the utilizing of dCas-based methods modifies chromatin states and gene expression to alter complicated features without altering the DNA sequence. Tiny and diverse CRISPR systems are the addition of Cas12 and other nucleases to Cas9 improves PAM compatibility and delivery options for plants.

CRISPR technology also helps in increasing the rate of reproduction or we can say reproductive potential of crops. By immediately generating chosen alleles, CRISPR reduces the length of breeding cycles, which in turn improves genomic selection pipelines. New, climate-resilient crops can be produced quickly by editing wild cousins to introduce domestication traits (such as non-shattering, plant architecture). Multiple editing is the method by which one can target many genes/pathways at once, allowing for stacked characteristics like improved stress tolerance and quality improvements.

Some of the exceptional examples of recent crop advancements with CRISPR technology can be discussed. Recent advances in major crops (rice and maize) emphasized as advancements in yield components, nitrogen use efficiency, drought/heat tolerance, and disease resistance. Across tomatoes and other horticultural species, CRISPR aimed to improve shelf life, texture, taste, and pathogen resistance in fruits and vegetables. Using molecular breeding that combines CRISPR with data science and phenomics for forage crops to enhance biomass, digestibility, and stress tolerance.

There are many delivery and DNA-free methods as well. DNA-free editing is one of them. In this method RNP and transient delivery reduces transgene footprints, which facilitates regulatory procedures and minimizes insertion problems. There are developments in tissue culture by Improved regeneration techniques enhancing editability in challenging crops, leading to broader use.

CRISPR technology ensures food security and environmental protection by reducing the use of agrochemicals. CRISPR-enabled resistance and nutrient usage efficiency can help maintain yields while lowering the use of fertilizers and insecticides. Climate resilience is essential for consistent output; specific modifications allow plants to withstand salinity, drought, heat waves, and emerging biotic dangers. With frameworks listed throughout regions and continuing to adapt, global regulation is changing to differentiate genome-edited crops (particularly those without foreign DNA) from transgenic GMOs. Although accurate, DNA free modifications are generally seen more positively, policy differences call for transparency and case by case adherence in product development.

There are many difficulties and obstructions along with the benefits provided by CRISPR technology in agriculture. These are specificity and off-targets, reliance on genotype and delivery, complex features. Specificity and off-targets can be explained as the ongoing development of guide design and nucleases lowers off-target effects while maintaining effectiveness. There are species-specific restrictions that prevent universal adoption across crops as well as transformation/regeneration hurdles, this is reliance on genotype and delivery. Polygenic architecture and pleiotropy demand multiplex approaches and astute trade-off management during editing.

Potential future avenues of this technology are many such as Integrating AI and high-throughput phenotyping, the lab-to-farm gap may be closed by speeding up allele discovery, edit prioritization, and field validation. New CRISPR systems are also potential scope of this technology, new editors and transposon-associated systems may facilitate targeted insertions and more programmable genome engineering in plants. Scalable implementation can be explained as integrating seed systems and local breeding schemes with careful editing improves fair influence on nutrition and resilience, this also has a great scope in future.

In conclusion of this article, I would like to discuss some important points, CRISPR is a precise breeding platform that allows for the quicker, programmable enhancement of key agronomic features that contribute to yield, resilience, and quality. The potential for base/prime editing, DNA-free delivery, and a variety of nucleases are all improving the range of possible edits and the predictability of their application in crops. Genome-edited plants are becoming increasingly well-positioned to make a significant contribution to sustainable agriculture and world food security because to advancements in technology and changes in regulations.

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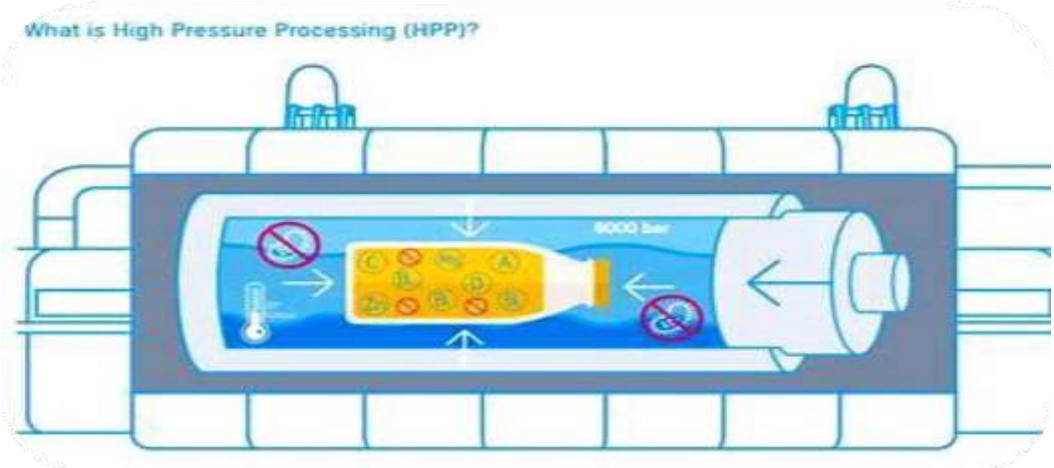
Microbial behavior against the newer methods of food processing, adoption and resistance development

Introduction

As food systems scale globally, the demand for fresher, safer, and minimally processed foods has driven a major shift in food processing techniques. Microorganisms—some beneficial, many harmful—remain persistent adversaries. Today, traditional methods like boiling or thermal pasteurization are being replaced or supplemented by non-thermal and precision technologies that enhance microbial safety while maintaining sensory and nutritional integrity.

These modern techniques don't just kill pathogens—they preserve nutrition, improve texture, and cut energy costs, aligning well with global trends in sustainable food systems. Let's explore how agricultural sectors are harnessing these tools to enhance safety, shelf life, and sustainability.

High Hydrostatic Pressure (HHP) Processing



Principle of HHP

High Hydrostatic Pressure (HHP) processing involves compressing food products uniformly in all directions. Upon pressure release, the food regains its original shape. The main components of an HHP system include:

- **Pressure Vessel**
- **Pressure Generating Device**
- **Material Handling System**
- **Temperature Controls**

HHP has a lethal effect on vegetative microorganisms due to changes in their membrane structures. The membrane is the primary site of disruption, leading to altered transport functions, internal physiochemical imbalances, and eventual cell death. The lethal pressure threshold is around **180 MPa**, beyond which cell viability declines exponentially. HHP inactivation is **multi-target in nature**.

HPP Against Microbes

1. **Endospores and HHP Resistance**
- Endospores can withstand pressures above **1000 MPa**.
2. Clostridium vs. Bacillus Spores
- **Clostridium spores** are more resistant to pressure than **Bacillus spores**.
3. Effect of Low Pressure on Spores
- Pre-exposure to **lower pressures** can increase spore sensitivity to higher pressures.
4. Gram-positive vs. Gram-negative Bacteria
- **Gram-positive bacteria** are more resistant to HHP than **Gram-negative bacteria**.
- **Cocci (round-shaped bacteria)** are generally more resistant than **rod-shaped bacteria**.
5. Why Gram-negative Bacteria Are Less Resistant
- Their **complex outer membrane** makes them more vulnerable to pressure.
6. Yeasts, Molds, and HPP
- Most yeasts and molds are sensitive to high pressure, but **heat-resistant molds** (e.g., *Byssochlamys*, *Neosartorya*, *Talaromyces*) have spores that resist pressure.
7. Viruses and HPP
   - HPP can **disrupt viral outer layers**, preventing them from binding to host cells.
8. Prions and HPP
- Prions are highly resistant to heat and pressure.
- Combining **HPP with 60°C** has been shown to affect prion structure, making them more vulnerable to enzymatic breakdown.
9. Inactivating Toxins with HPP
- **Staphylococcal enterotoxins** in food (e.g., cheese) can be completely eliminated with HPP.

Pulsed Electric Field (PEF)

- PEF is a non-thermal (doesn’t use heat) method for killing microorganisms.
- It involves use of **short pulses of high electric voltage (upto 5-50 kV/cm) for microseconds to milliseconds** which decontaminates the food followed by aseptic packaging and refrigeration.
- The electric field creates **pores in the microbial cell membrane** in a process called electroporation.
  If the pores close after the electric pulse, the cell survives (**reversible electroporation**).
- If the pores remain open, the cell loses its contents and dies (**irreversible electroporation**).
- The pulse electric field system is composed of three units: **a treatment chamber (consist of a set of electrodes), a high voltage pulse generator, a control system for monitoring the process.**
- The food is placed between the electrodes in a treatment chamber which is exposed to short pulses of high electric voltage. The two electrodes are connected to non-conductive material to prevent the electric flow from one to another.

- The food product experiences a force as electric field, which is responsible for the cell membrane breakdown in microorganisms and causes inactivation of microorganisms. The process is majorly equipped for pasteurization of food products including eggs, juices, milk, soups and yogurt.

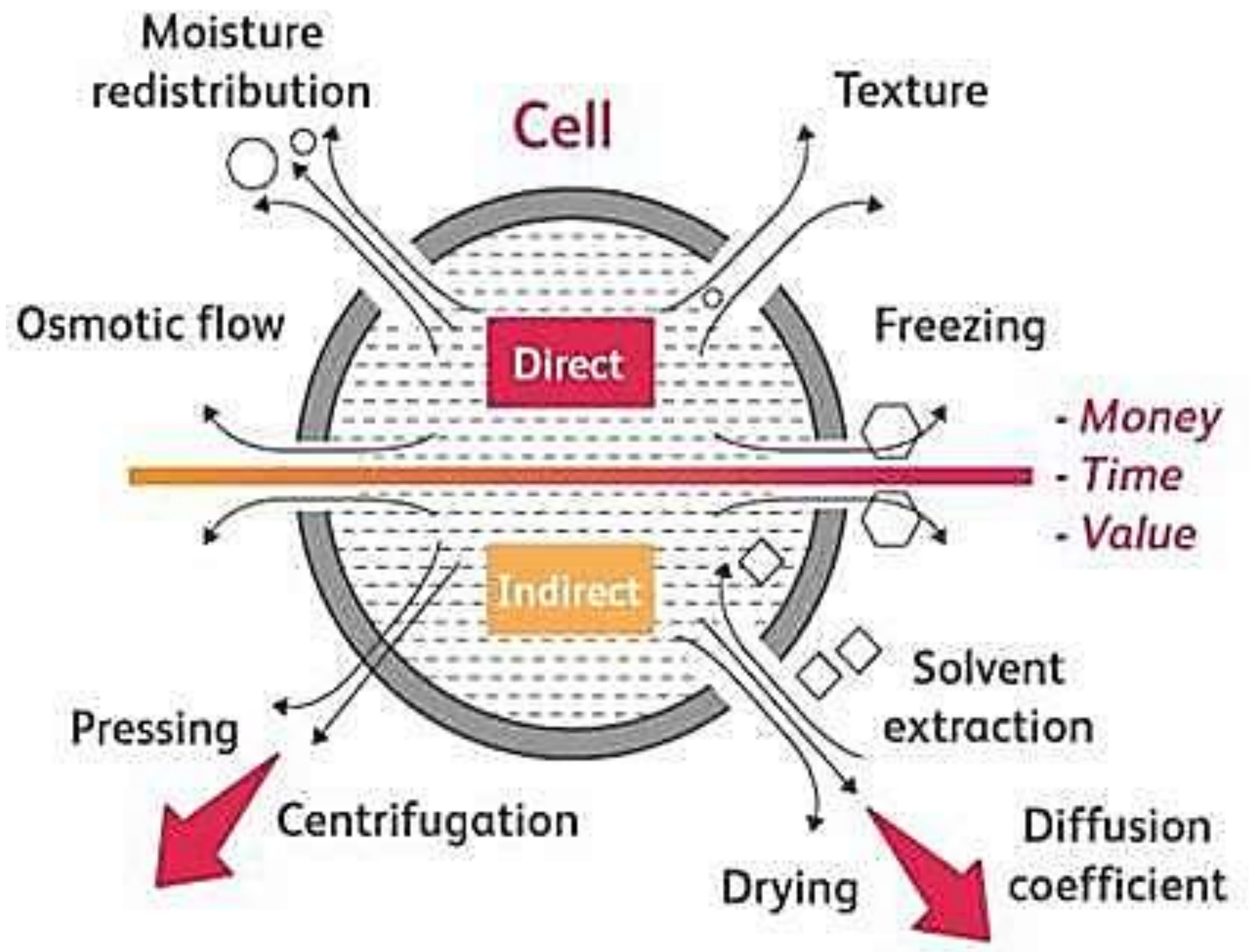
  Example: If a microorganism is like a balloon filled with water, PEF creates tiny holes in the balloon. If the holes are small, the balloon can reseal (reversible electroporation). But if the holes are too big, the water leaks out and the balloon collapses (irreversible electroporation).

2. How Does PEF Kill Microorganisms?

- When PEF is applied, it increases the **transmembrane potential** (the voltage difference across the cell membrane).
- If this voltage reaches a **critical level (250–500 mV)**, the cell membrane structure is disrupted, forming **pores**.
- If the electric pulses are strong and long enough, the pores **fail to reseal**, causing permanent damage and cell death.

Key effects:

- The cell loses **water, ions, and essential molecules**, leading to death.
- The electric pulses can also disrupt **intracellular structures**, like mitochondria or proteins, further killing the cell.
- If PEF duration is too short, the cell **might not die**, but can become **weakened or**



stressed, making it more vulnerable to antibiotics or other treatments.

3. Impact of PEF on Different Microorganisms

PEF affects different microbes differently based on **cell size, structure, and membrane composition**.

(A) Larger vs. Smaller Microorganisms

- **Larger cells (e.g., yeast like Saccharomyces cerevisiae)**
  - Have **higher transmembrane potential** (because their membranes cover more area).
  - This makes them **more vulnerable** to electroporation, meaning they are easier to kill with PEF.
- Smaller cells (e.g., bacteria like E. coli)
  - Have **lower transmembrane potential** and a **stronger membrane structure**.
  - These require **higher PEF intensity** or longer exposure to be killed.

(B) Gram-Positive vs. Gram-Negative Bacteria

- **Gram-positive bacteria (e.g., Staphylococcus aureus)**
  - Have a **thick peptidoglycan layer** that offers **more resistance** to electroporation.
  - Are **less sensitive** to PEF compared to Gram-negative bacteria.
- Gram-negative bacteria (e.g., E. coli)
  - Have a **thinner cell wall** but an **outer membrane with lipopolysaccharides**.
  - This makes them **more vulnerable** to electroporation, but some can still survive PEF treatment.

(C) Endospores and Antibiotic-Resistant Bacteria

- **Endospores (e.g., Bacillus subtilis)**
  - Spores are highly resistant to **heat, chemicals, and radiation**.
  - PEF alone is **not very effective**, but **combining PEF with heat** can kill them.
- Antibiotic-resistant bacteria (e.g., MRSA, drug-resistant E. coli)
  - PEF **weakens** their defenses, making them more susceptible to antibiotics.
  - When combined with antibiotics, PEF can **restore drug effectiveness** against resistant bacteria.

Ultrasound

1. What is Ultrasound in Microbial Inactivation?

- **Ultrasound** refers to **sound waves with a frequency above 20 kHz** that **humans cannot hear**.
- When used in food processing, it can kill bacteria **by creating pressure changes** that damage cell membranes.
- Two types of ultrasound:

1. **Low-power ultrasound (above 100 kHz)** – Used for analyzing food quality.
2. **High-power ultrasound (20–100 kHz)** – Used for killing microbes.

2. How Does Ultrasound Kill Microorganisms?

- **Main method: Cavitation**
  - Ultrasound creates **high-pressure and low-pressure cycles** in liquids.
  - Tiny **gas bubbles form and collapse violently**, releasing energy.
  - This **damages bacterial membranes**, making them weak or killing them.
- Other effects include:

- **Local heat generation** – Creates small **hot spots** that can kill bacteria.
- **Production of free radicals** – These are highly reactive molecules that can damage bacteria.
- **Shear forces** – The movement of liquid can **tear apart** bacterial cells.

- Ultrasound **alone is not very effective** in killing bacteria.
- When combined with **heat and/or pressure**, its ability to kill bacteria improves significantly.
- Three common combined treatments:

1. **Thermosonication** – Ultrasound + Heat.
2. **Manosonication** – Ultrasound + Pressure.
3. **Manothermosonication** – Ultrasound + Heat + Pressure (most effective).

4. Effects of Ultrasound on Different Bacteria

A. Listeria monocytogenes (L. monocytogenes)

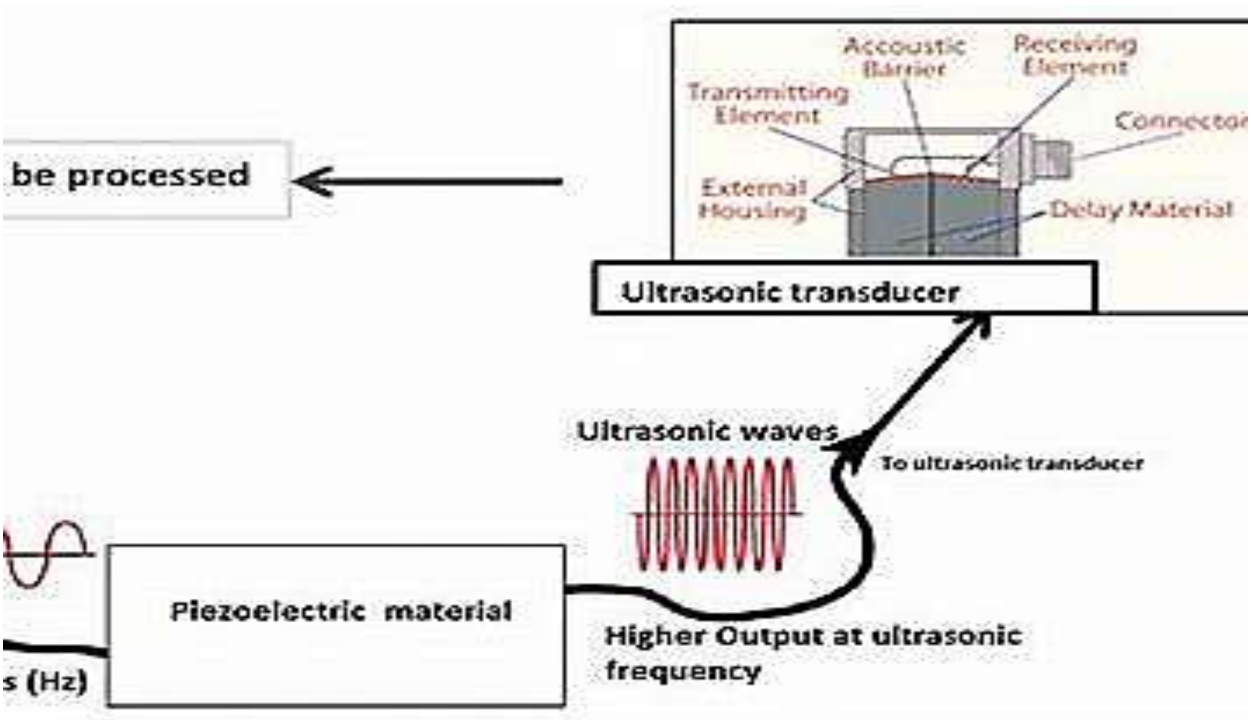
- **Ultrasound alone is weak** against Listeria.
- Adding pressure (Manosonication) improves inactivation.
    - At **200 kPa pressure**, ultrasound killed **Listeria 3× faster** than normal.
    - At **400 kPa pressure**, it killed **Listeria 4× faster**.
- **Adding heat (Thermosonication) was even more effective**, especially above **50°C**.

B. Salmonella spp.

- Ultrasound **alone does not kill Salmonella effectively**.
- When combined with **chlorine**, it improves **Salmonella reduction on food surfaces**.
- Ultrasound in chocolate processing:
    - 26% bacteria killed in **10 minutes**.
    - 74% bacteria killed in **30 minutes**.
    - But the chocolate **got too hot**, meaning heat also played a role.

C. Escherichia coli (E. coli)

- Ultrasound at **24 kHz** successfully reduced



E. coli.

- **Intensity did not matter much** – all power levels had similar results.
- Ultrasound + Antibiotics:
  - E. coli was **97% removed** in biofilms when treated with ultrasound + antibiotics.
  - The ultrasound **helped the antibiotic penetrate bacterial membranes**.

D. Bacillus subtilis (B. subtilis)

- B. subtilis **spores are highly resistant** to ultrasound alone.
- **Thermosonication (Ultrasound + Heat) significantly reduced spores**.
- **Manothermosonication (Ultrasound + Heat + Pressure) was the best**:
  - It **reduced spore resistance by 90%**.
  - At **500 kPa pressure**, microbial inactivation was highest.

Conclusion

Modern food processing techniques like **High Hydrostatic Pressure (HHP)**, **Pulsed Electric Field (PEF)**, and **Ultrasound** are transforming food safety by effectively inactivating harmful microorganisms while preserving food quality. These methods offer advantages over traditional thermal processing, such as maintaining nutritional value and reducing energy use. However, challenges remain with resistant microbes like endospores and prions, necessitating combined approaches for optimal results. As the food industry evolves, these technologies will play a key role in meeting the demand for safer, fresher, and more sustainable food systems.

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Global Climate Change and Indian Agriculture: Weather Disruptions and the Urgent Need for Climate-Resilient Crop Varieties

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About Global Climate Change

Global climate change has emerged as one of the most formidable challenges of the 21st century, impacting every aspect of the environment and human society. Defined by long-term shifts in temperature, precipitation, wind patterns, and other aspects of the Earth's climate system, this phenomenon is primarily driven by human activities, notably the burning of fossil fuels, deforestation, and industrial emissions. These activities increase the concentration of greenhouse gases (GHGs) such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) in the atmosphere, enhancing the greenhouse effect and causing global temperatures to rise. For example; Industrial sectors contributed 24% of global emissions in 2019, including CO_2, methane (CH_4), and nitrous oxide (N_2O) (IPCC 2023). the planet is already about 1.2°C warmer than in the late 1800s, and greenhouse gas emissions reached a record high of 57.1 gigatons of CO2 equivalent in 2023—up 1.3% from 2022. (UNEP Emissions Gap Report 2024.) The resulting changes in climate are not uniform; their effects vary across different regions, with developing countries like India being particularly vulnerable due to their economic and social conditions.

Image Source: World Wide Fund for Nature website

Climate Change in Indian Context

India, with its vast geographical diversity and heavy dependence on agriculture, is acutely sensitive to the impacts of global climate change. The country experiences a wide range of climatic zones, from the Himalayas in the north to the coastal regions in the south, and from arid deserts in the west to humid tropical areas in the east. This climatic diversity means that any shift in global climate patterns can have far-reaching and varied consequences for India's weather systems. Over the past few decades, India has witnessed a significant increase in extreme weather events, including heatwaves, floods, droughts, and cyclones, which have become more frequent and intense. **Human-induced climate change has increased the frequency and intensity of extreme events**, especially in South Asia (IPCC AR6 2021). Events like **heatwaves, droughts, and tropical cyclones** are now more intense and more likely due to global warming. These changes are disrupting traditional weather patterns and posing serious threats to food security, water resources, health, and livelihoods

Climate change and Indian Agriculture

Image Source: Global Association of Risk Professionals website

In addition to changes in precipitation patterns, rising temperatures are another critical aspect of climate change affecting India. Average temperatures across the country have been steadily increasing, with many regions experiencing record-breaking heatwaves in recent years. High temperatures lead to heat stress in crops, reduce soil moisture, increase evapotranspiration, and can even result in the failure of pollination in certain crops. Moreover, higher temperatures can exacerbate pest and disease outbreaks, further threatening crop productivity. For instance, wheat, which is a staple rabi crop, is highly sensitive to temperature fluctuations during the grain-filling stage. An increase of even 1°C in temperature during this period can lead to a significant reduction in yield.

Changing Weather Patterns Due to Global Climate Change

Image Source: NASA Science website

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staple rabi crop, is highly sensitive to temperature fluctuations during the grain-filling stage. An increase of even 1°C in temperature during this period can lead to a significant reduction in yield. heat stress during the grain-filling stage significantly impacts wheat yields, citing that during the grain-filling season, estimated grain yield losses in South Asia range from 6 to 10% per °C increase in temperature, and demonstrates the physiological mechanisms behind these losses. (Heat stress in wheat, Report, 2023)

Additional Sectors Impacted by Global Climate Change

The impacts of climate change are not limited to crops alone; they extend to livestock, fisheries, and forestry as well. Livestock are susceptible to heat stress, which can lead to reduced milk production, reproductive issues, and higher mortality rates. Changes in climate also affect the availability and quality of fodder, thereby impacting livestock health and productivity. Climate change has already reduced livestock productivity due to **heat stress**, **disease outbreaks**, and **reduced forage quality**. Animals consume **3–5% less feed per additional degree of warming**, leading to lower fertility and milk yields (IPCC Sixth Assessment Report, 2022). In the fisheries sector, rising sea surface temperatures and ocean acidification are altering fish breeding patterns and migration routes, affecting the livelihoods of coastal communities. Tropical fisheries are especially vulnerable, with projected declines in catch potential of up to **40% by 2050** in some regions. Forest ecosystems, which play a vital role in maintaining ecological balance and providing resources to millions of people, are also under threat due to increased incidences of forest fires, pest infestations, and loss of biodiversity. Increased frequency of wildfires, pest outbreaks, and droughts are degrading forest ecosystems.

Mitigation and Adaption

Climate-resilient crop Varieties- Need of the Hour

Image Source: World Bank Website

Given these multifaceted challenges, there is an urgent need for adaptive strategies to make Indian agriculture more resilient to climate change. One of the most effective and immediate solutions is the development and dissemination of climate-resilient crop varieties. These are varieties that have been specifically bred or genetically modified to withstand various climatic stresses such as drought, flood, salinity, and heat. By maintaining stable yields under adverse conditions, these crops can play a crucial role in ensuring food security and protecting farmers' incomes.

In recent years, Indian agricultural research institutions, particularly the Indian Council of Agricultural Research (ICAR), have made significant strides in developing climate-resilient crop varieties. Under the National Innovations in Climate Resilient Agriculture (NICRA) project, ICAR has released several such varieties that are already making a difference on the ground. For instance, Swarna-Sub1 is a flood-tolerant rice variety that can survive complete submergence for up to two weeks, making it ideal for flood-prone areas in eastern India. Similarly, The Indian Agricultural Research Institute (IARI) has developed a drought-tolerant Basmati rice variety called Pusa Basmati (PB) 1882. This variety is recommended for cultivation in Haryana, Punjab, Western Uttar Pradesh, Uttarakhand, and Jammu & Kashmir. It is designed to withstand deficient rainfall during the flowering stage of the grain. Other examples include heat-tolerant wheat varieties like HD 3385 and HD 3086.

The adoption of these resilient varieties has shown promising results in terms of yield stability, reduced crop loss, and improved income for farmers. However, the success of such initiatives depends on several factors, including awareness among farmers, availability of quality seeds, extension services, and supportive government policies. There is a need to strengthen the seed production and distribution systems to ensure timely and affordable access to these varieties. Additionally, capacity-building programs and demonstration plots can help in educating farmers about the benefits and best practices related to resilient agriculture.

While resilient crop varieties form the cornerstone of climate adaptation in agriculture, they need to be complemented by other measures such as improved irrigation practices, soil health management, crop diversification, and the use of information and communication technologies (ICTs) for weather forecasting and advisory services. For instance, micro-irrigation techniques like drip and sprinkler systems can enhance water use efficiency and reduce the dependence on erratic rainfall. Integrated nutrient and pest management practices can improve soil fertility and reduce the risk of crop damage due to pests and diseases. Diversifying crops and integrating livestock and fisheries into farming systems can provide additional income and reduce risk.

Strengthening Meteorological information dissemination system

Accurate and timely weather forecasting is another critical component of climate-resilient agriculture. The India Meteorological Department (IMD), in collaboration with ICAR and other agencies, provides weather-based agromet advisories to farmers through the Gramin Krishi Mausam Sewa (GKMS) program. These advisories include information on weather conditions, crop management practices, pest and disease warnings, and irrigation scheduling. With the widespread use of mobile phones and digital platforms, these advisories are now reaching millions of farmers across the country. However, there is still scope for improvement in terms of forecast accuracy, localization of advisories, and integration with other decision-support tools.

International Cooperation and United Efforts against Global Climate Change

Image Source: MRSC Website

In addition to national efforts, climate change adaptation in Indian agriculture also requires international cooperation and support. As a signatory to the Paris Agreement, India has committed to reducing the emissions intensity of its GDP by 33-35% by 2030 and enhancing the adaptive capacity of vulnerable sectors (India's Fourth Biennial Update Report to UNFCC, 2022). Climate finance from developed countries, technology transfer, and capacity building are essential to achieve these goals. Programs such as the Green Climate Fund (GCF) can provide much-needed resources for scaling up climate-resilient agriculture and supporting rural livelihoods.

Role of Community, Women via Capacity Building

The importance of community participation and local knowledge in climate adaptation cannot be overstated. Farmers have a deep understanding of their local environments and have traditionally employed various coping mechanisms to deal with climate variability. Incorporating this indigenous knowledge into scientific research and policy-making can enhance the effectiveness and sustainability of adaptation strategies. Participatory breeding programs, community seed banks, and farmer field schools are some of the approaches that can help in this regard. Moreover, the role of women in agriculture and climate resilience deserves special attention. Women constitute a significant proportion of the agricultural workforce in India and are often responsible for critical farming activities. However, they face multiple barriers, including limited access to resources, information, and decision-making power. Empowering women through targeted interventions, training programs, and inclusive policies can significantly enhance the adaptive capacity of farming communities. Education and awareness are key to building a climate-resilient future. Integrating climate change and sustainable agriculture into school and university curricula can prepare the next generation to deal with these challenges. Public awareness campaigns, media engagement, and the use of local languages and folk media can help in reaching diverse audiences and promoting behavioural change.

Conclusion

In conclusion, global climate change poses a serious threat to Indian agriculture and rural livelihoods. Its impacts on weather patterns, crop productivity, and natural resources are already being felt across the country. However, with proactive and integrated strategies, it is possible to build resilience and safeguard food security. The development and adoption of climate-resilient crop varieties, supported by improved irrigation, soil health management, weather forecasting, and community participation, offer a viable pathway to adaptation. Policymakers, researchers, farmers, and civil society must work together to create an enabling environment for sustainable and climate-resilient agriculture. Only through collective action and a long-term vision can India overcome the challenges of climate change and ensure a secure and prosperous future for its people.